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# MAP WORK

309

*by*

PHYLLIS DINK

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# PREFACE TO THE FIRST EDITION

This small volume is intended for students of Geography, preparing for the Intermediate Examination of Indian Universities, where the subject of Map Work has been receiving increased attention during recent years. Map work forms the laboratory of the geography student.

In compiling this book I have kept in view the limited knowledge of mathematics an average Intermediate student possesses. The syllabii of various Indian Universities vary; portions not included in the Intermediate syllabus of the Punjab University are printed in small type.

Useful exercises, some of which are selected from University Intermediate Examination Papers, are given at the end of each chapter.

I claim no originality in preparing this book and, therefore, deserve no eulogies that this book may earn. I acknowledge with gratitude the help I have received from books mentioned in the Bibliography.

March, 1938. P. D.

# PREFACE TO THE SECOND EDITION

A major portion of the book has been re-written to bring it up to the requirements of the new syllabus in Map Work. One of the principal objects has been to treat the subject from a practical point of view. Minor rearrangements and important additions, which experience has shown to be desirable, have been made.

Map Work has a wide field; it is because of its contact with surveying that the chapter on Field work has been retained, though in a very much reduced form.

June, 1942. P. D.

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# ESSENTIALS

The student should provide himself with the following instruments and materials :

1. A good pair of compass fitted with both pencil and pen points. The pencil point should be kept thin and round.
2. Adrawing pen.
3. Pencils—two are necessary—H and 2H.
4. A pair of Dividers.
5. Set squares and T square.
6. Indian Ink.
7. India rubber
8. Protractor—A "Service Protractor" will be better
9. Drawing copy book.
10. Graph paper.
11. Drawing box.
12. Ruling pen.
13. French curves
14. Bevelled ruler.

# MEMORANDA

100 links = 1 chain
10 chains = 1 furlong
80 chains = 1 mile.

1 link = 7·92 inches = 8 in. (nearly).
1 chain = 66 ft = 22yds.
1 long chain = 100 ft.

---

1 kilometre (km) = 1000 metres
1 metre = 10 decimetres (dm)

1 metre = 100 centimetres (cm).
1 centimetre = 10 millimetres (mm).

---

1 fathom = 6 ft.

1 nautical mile = 1·1515 statute miles

---

1 metre = 1·094 yards = 39·371 inches.

---

12 inches = 1 foot.
3 feet = 1 yard
5½ yards = 1 pole, rod or perch.
4 poles = 1 chain.

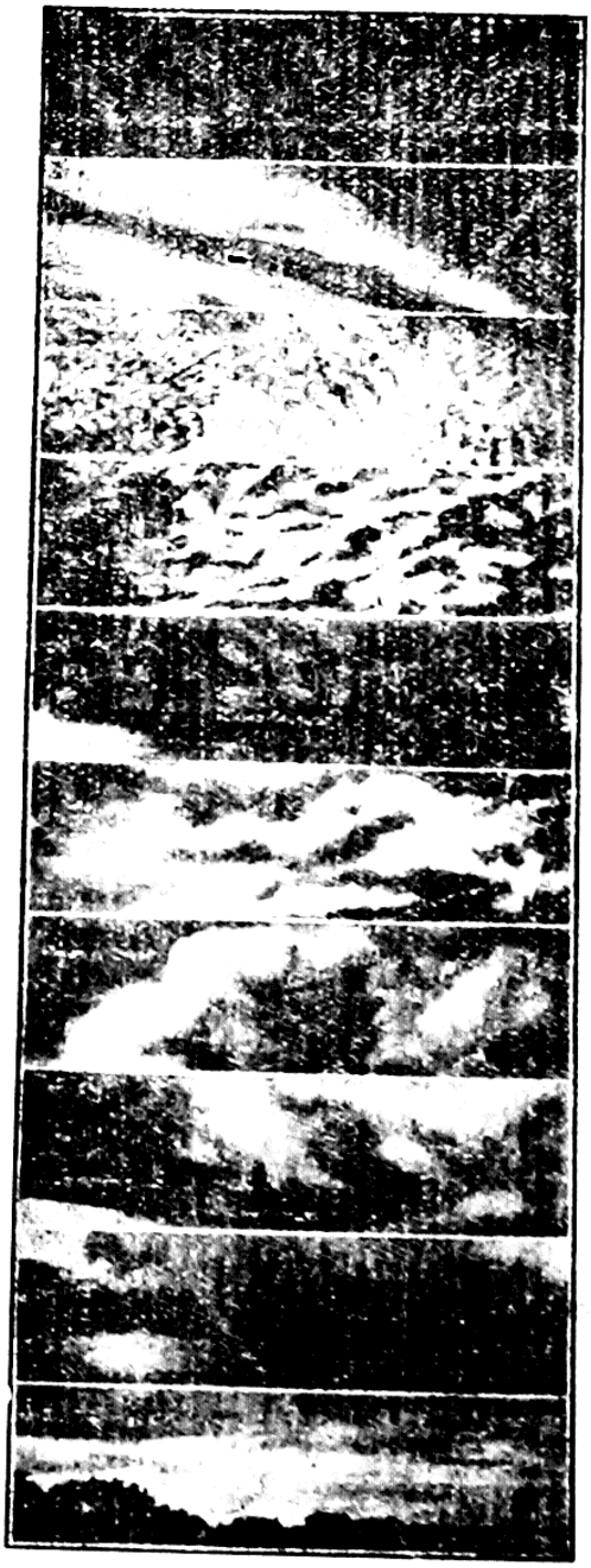
10 chains = 1 furlong
8 furlongs = 1 mile (1,760 yards).
3 miles = 1 league.

---

1,000 millibars = 1 bar = 29·53 inches of mercury.
1 in. of mercury = 33·86 millibars.

n.p.
1 pace = 2½ [illegible] feet

CLOUD FORMS



[*Frontispiece*

# MAP WORK

## CHAPTER I

### MAPS AND SCALES

1. **Maps.** A map is a flat representation of a large or small area of ground. Maps give us a permanent record of the various features on the earth's surface. Their study is very important; they form the laboratory of the geographer.

A map may be regarded as a conventional picture of the Earth's surface as seen from above, to which lettering is added for identification.

An aeroplane photograph gives us a true facsimile of the earth's surface on a small scale. A map, however, is different from an aeroplane photograph; in a map, we need to have a place for names; roads etc. are not true to scale.

A map, in other words, is some fraction of the true size of the area on the ground shown on the map; this fraction is known as the "scale" of the map. Thus when we speak of the scale being 1 inch = 1 mile, we mean that two points one inch apart on the map are one mile apart on the ground. One mile is equal to 63,360 inches (1,760 × 3 × 12), hence we may speak of the scale as $\frac{1}{63360}$ which means that one inch on the map represents 63,360 inches on the ground.

The term **Map work** includes a study of the various types of maps, the methods and principles underlying their construction, and the various methods of showing landscape and the different phenomena on the earth's surface. Sometimes the term **Cartography** is used for the science of map construction.

In fact there are three aspects to our study; the land is measured by the surveyor, the measurements are collected and rendered on a map by the cartographer and the facts shown are interpreted by the geographer.

2. **Charts and Plans.** The word "chart" is derived from the French *carte* meaning a map and hence there is an overlapping between the words "map" and "chart". A chart is usually a record of the submerged portion of the earth's surface; thus steamship routes are shown on charts of various oceans.

The distinction between a map and a plan is a matter of convention. The word "plan" is usually used in connection with property surveys, *e.g.*, the plan of a building by an architect. The scale of a plan is usually greater than 6″ = 1 mile; while the scale of a map may be anything smaller than 6″ = 1 mile. These plans are sometimes known as *cadastral maps* from a French word *cadastre* meaning a detailed register of territorial property.

**3. Types of Maps.** Maps may be classified into the following types, the object of classification being to show only certain features of the area mapped to avoid confusion :—

(1) An **outline map** shows only the coast-line of a country or a continent.
(2) A **political map** shows the political boundaries, provinces, towns, rivers and railways, etc.
(3) A **relief** or **physical** or **orographical map** shows the nature of the surface of the land ; various colours may be used to distinguish high land from low land etc.
(4) A **bathymetric map** shows the varying depths of the ocean, *e.g.*, by using various shades of blue, and indigo-blue.
(5) A **bathy-orographical** map is a combination of Nos. 3 and 4 above.
(6) A **vegetation map** shows the distribution of natural vegetation.
(7) A **biological map** shows the distribution of vegetation, animals and races of mankind.
(8) An **ethnographical map** shows the distribution of races of mankind only.
(9) A **climatic map** shows temperature, rainfall, pressure and wind systems for any particular season or as an average for a considerable number of years. In wall-atlases two sets of climatic maps—one for summer or July and the other for winter or January—are usually prepared.
(10) A **weather map** shows the temperature, rainfall, pressure and wind systems for any particular day from data founded on observations made at various observatories.
(11) A **commercial** or **economic map** shows the centres of production of various commodities, direction of trade, density of population, etc.
(12) A **distributional** or **commodity map** shows the distribution of crops, animals, minerals or people in a given area by actual figures on a quantitative basis.
(13) A **geological map** shows the various types of rocks, their nature and age, inclination of the various beds of rock, soil, water-supply etc., in relation to the upper part of the earth's crust.
(14) A **topographical map** is a large scale map (usually less than 6″ = 1 mile) based upon actual survey of the land ; it presents general information and shows details of both natural and man-made features.
(15) The **International map** is a survey map on a scale of 1 : 1,000,000 (1/M) as a result of the co-operation of various countries. It is divided into sheets, which are uniform in scale, size, conventional signs, and style of drawing.

Besides the above we have the **historical map** giving main facts of history of any country for any particular period ; **astronomical charts** depicting the astronomical phenomena of the universe, *e.g.*, the motion of the planets round the sun ; **charts** used for navigation ; and maps used in art and in advertising.

**4. Scales and their Construction.** If the distance between two stations is one mile on the ground, and these two stations are one inch apart on a map, the relationship that exists between these two distances will be called the scale of map; in this case one inch to one mile. A *scale* denotes the proportion which a length on a map or plan bears to the actual length on the ground. The representation of the distance on maps may be done in three different ways :—

(1) The Statement of the Scale.
(2) The Representative Fraction or Numerical Scale.
(3) The Plain or Linear Scale, also known as Graphic Scale.

5. **The Statement of the Scale.** A statement of the scale is inserted on the map thus ;

10 ft. = 1″
1 mile = 1″
5″ = 1 mile

The scale is always appended on maps, so that the actual distance represented can be readily calculated.

Scales may be either small or large.

Small scales are scales of *miles to the inch*, e.g.—

4 miles = 1″
64 miles = 1″

Atlas maps are on small scales.

Large scales are scales of *inches to the mile*, e.g.,

2″ = 1 mile
6″ = 1 mile

Survey maps, Artillery and Trench maps are large scale maps.

6. **The Representative Fraction.** In this case, the proportion existing between length on the plan and on the actual ground is indicated by a fraction whose numerator is 1. Such a fraction is called a "Representative Fraction" and is usually abbreviated to R. F. Thus :

$$\text{R. F.} = \frac{\text{Map distance}}{\text{Ground distance}}.$$

If a map has an R. F. $= \frac{1}{1{,}000}$ it indicates that any length on the map represents 1,000 times that length on the ground, whether it be in inches, centimetres, feet or yards, etc.

**Example 1.** 1 inch to a mile = 1 inch to $1760 \times 3 \times 12$ inches
= 1 inch to 63,360 inches.

Hence $$\text{R. F.} = \frac{1}{63{,}360}$$

This scale is independent of units and is applicable to all countries.

7. **Plain Scales.** Sometimes a line is drawn at the bottom of the map conveniently sub-divided, so that the reduced distances can be directly measured ;

such a device is known as a 'plain scale.' The following points must be borne in mind in constructing a scale:—

(1) The scale should be fairly long (usually about 6 inches) so that the longest measurement may be made directly from it.

(2) It must represent a convenient round number of the unit employed.

**Example 2.** *Construct a plain scale of 7 miles to the inch.*

As stated above a convenient length for a scale is usually about 6 inches.

A line 6 inches long will show 6×7=42 miles on the given scale. Let us take the nearest round number 40 miles to show the primary divisions and subdivide it into 8 parts; each part will show $=\frac{40}{8}=5$ miles. Add another 5 miles for the subdivisions on the left of zero to show secondary division.

We have, therefore, to construct a scale to show $40+5=45$ miles in all, *i.e.*, both for primary and secondary divisions.

As

$$7 \text{ miles} = 1 \text{ inch}$$

$$\therefore \quad 45 \text{ miles} = \frac{45}{7} \text{ inches}$$

$$= 6{\cdot}42 \text{ inches}$$

We thus draw a line AB=6·42 in. and subdivide it into 8+1=9 parts.

Take a line AB=6·42 inches. From A draw AC a little longer than AB and making an angle of about 30° with AB. On AC, with dividers mark off nine points *a*, *b*, c,......*i* at equal distances, taking care that the last division mark is *approximately* below B. Join the last point *i* to B and from other points draw lines parallel to *i*B; these lines cut AB and give the required divisions. Each division=5 miles.

Beginning from the second, write the primary divisions thus:

0, 5, 10, 15, 20, 25, 30, 35, 40

Sub-divide the first division into 5 equal parts as shown in the diagram. Each of these smaller divisions=1 mile. They are known as the secondary divisions.

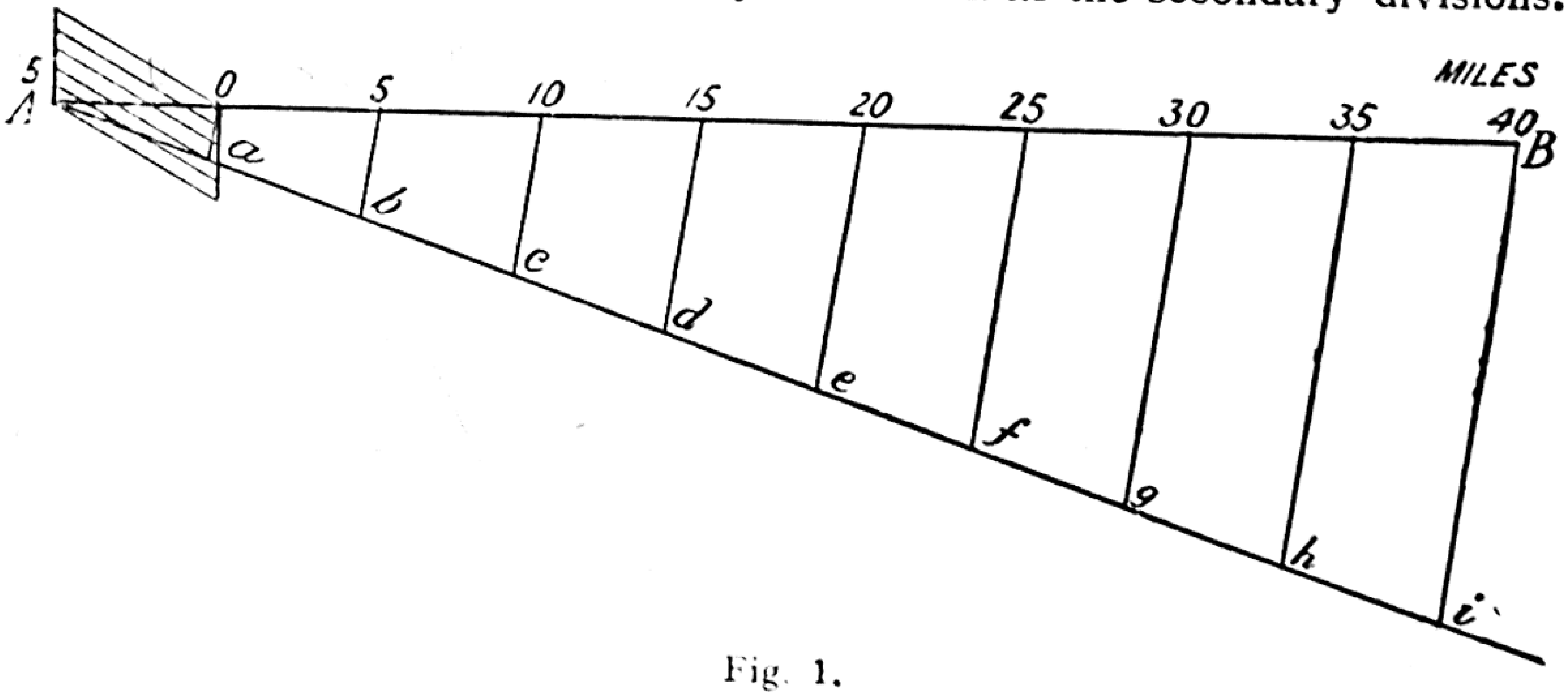


Fig. 1.

**Example 3.** *Construct a plain scale to show yards on a scale of 4 inches to the mile.*

The scale given is

$$4 \text{ inches} = 1 \text{ mile} = 1760 \text{ yards}$$

$$\therefore \quad 6 \text{ inches will show } \frac{6}{4} \times 1760 \text{ yards}$$

$$= 2640 \text{ yards.}$$

Let us take a round number, say 2,500 for the primary divisions: if we subdivide it into 5 parts, each part will show 500 yards. Add another 500 yards for the secondary divisions. Thus the total length to be shown would be 2,500 + 500 = 3,000 yards. According to the given scale 1,760 yards = 4 inches.

$$\therefore \text{ 3,000 yards} = \frac{3000 \times 4}{1760} \text{ inches.}$$

$$= 6{\cdot}81 \text{ inches.}$$

Draw a line 6·81 inches long and divide it into 5 + 1 = 6 parts as explained in Ex. 1. Each of the divisions would represent 500 yards.

Write the divisions thus on the scale:—

500 0 500 1,000 1,500 2,000 2,500 yards.

Sub-divide the first division into five equal parts, each to show 100 yards.

The *plain scale* has the great advantage of remaining true after the map has been reproduced by photographic processes.

**8. Diagonal Scale.** An ordinary ruler is usually divided into tenths of an inch and cannot be used to measure a hundredth part of an inch. Such measurements can be got from a diagonal scale. The construction and use of a diagonal scale can be seen from Fig. 2 which reads to hundredths of an inch. Each of the diagonal lines progresses over one-tenth of an inch, so that each intersection with one of the parallel lines marks another hundredth of an inch.

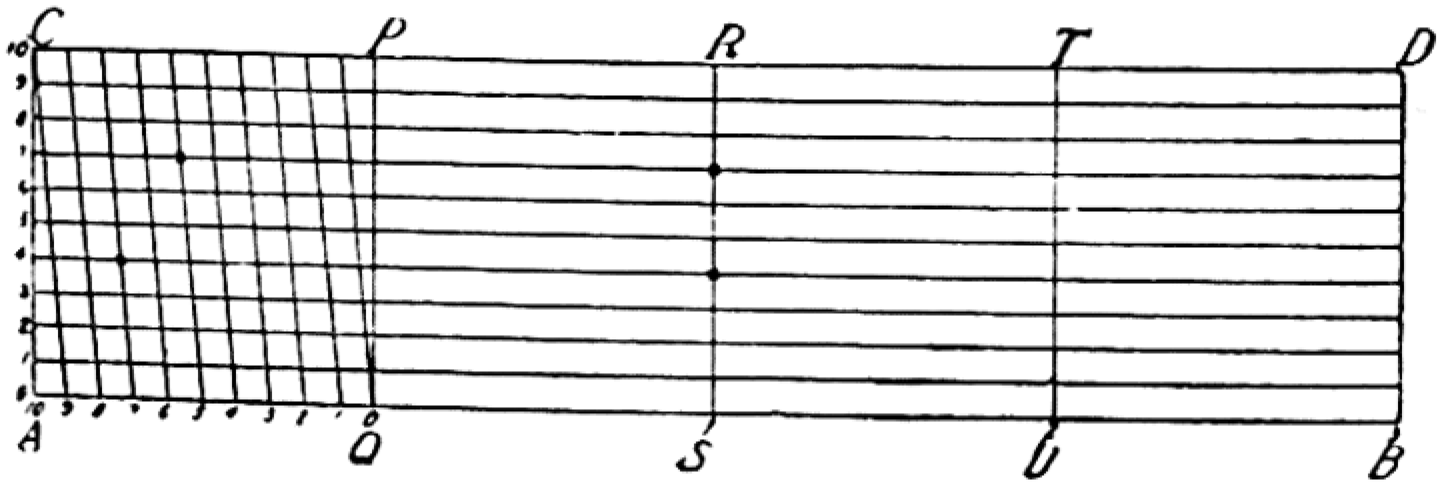


Fig. 2.

**9. Change of Scale.** A map may be drawn on a new scale, so that measurements on the new scale may be made directly. One of the simplest methods of enlargement or reduction is by squares.

Draw a set of squares on the original map, and prepare a similar set for the new map. The sides of the square in each case must be proportioned to the required representative fraction. Number both sets of squares to correspond, starting in each case from the top left hand corner. Transfer the points where the features shown on the map cross these lines from one set of squares to the other.

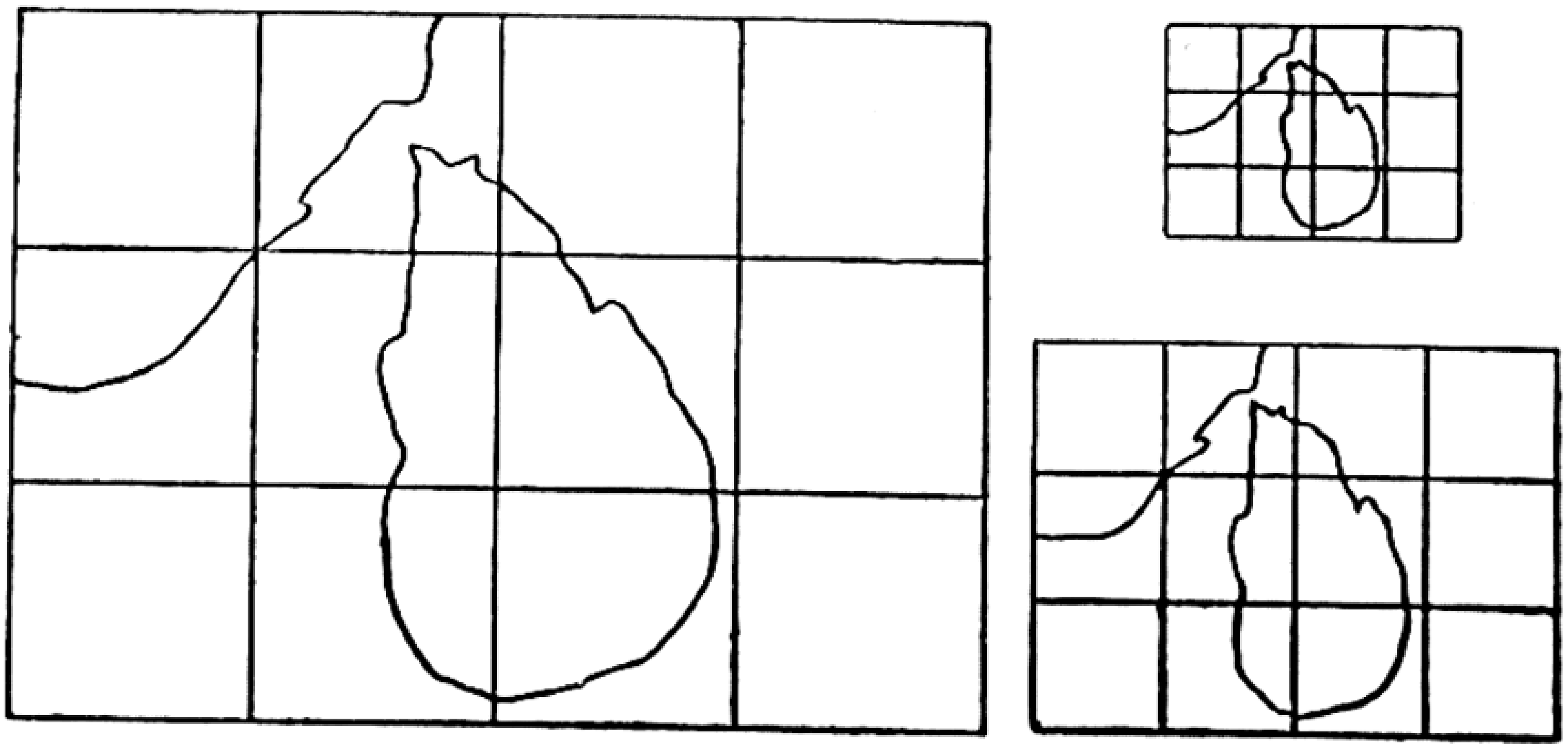


Fig. 3.

If a map has no scale, its scale can be found as follows: find the length of one degree of latitude in the centre of the map or on a straight meridian; this is approximately equal to 69 miles.

**Example 4.** *One degree of latitude on a map was found to be=1·5 inches.*

$$\text{R. F.}=\frac{1\cdot5}{69\times63{,}360}=\frac{1}{2{,}914{,}560}$$

## EXERCISES

1. Convert the following scales to R. F.—
   (*a*) 6 inches to a mile, (*b*) 1 centimetre to 1 kilometre, (*c*) 1 inch to 200 links.
2. Construct a scale of 5 inches to 1 mile.
3. Construct a scale of $\frac{1}{50{,}000}$ to show miles.
4. Construct a scale of 100 paces to 1 inch [1 pace=30 inches].
5. The R. F. of a map is given as $\frac{1}{400{,}000}$; how many miles are represented by one inch?
6. The R. F. of a map is given as $\frac{1}{100{,}000}$; how many inches represent one mile?
7. Draw a map of the Punjab on paper ruled in one-tenth inch squares. (*a*) Reduce it to half the scale; (*b*) enlarge it to double the scale.
8. Construct a plain scale for 2 miles=1 inch to show yards.
9. Draw suitable scales in (*a*) inches to the mile, (*b*) centimetres to the kilometre for the International Map whose R. F.$=\frac{1}{\text{M}}$.
10. Find the R. F. of the following scales :—
    5 miles=1″ ; 5″ =1 mile ;
    ½ cm. =1 km. ; 2 cm. =1 km.

**11.** Construct a scale of 4 miles = 1" to show half-miles.

**12.** A motorist travelling at 50 miles an hour covers the distance between Lahore and Mughalpura in 6 minutes. If the distance on the map between Lahore and Mughalpura is 3", what is the R. F. of the map ? Also construct a plain scale to show miles.

**13.** A map is to be made on horse-back to show a tract of country on a scale of 3 inches = 1 mile. The horse trots at 6 miles per hour. Construct a suitable time scale for this purpose.

**14.** A dilapidated map has the scale torn off and missing. The distance between two places on the map as being 1·25 inches is measured to be = $3\frac{1}{2}$ miles. Construct a scale for the map.

**15.** (*a*) What do yo understand by (1) map, (2) map projection, and (3) scale.

(*b*) The distance between London and Constantinople on a map drawn to a scale of 1 ; 12,000.000 is $8\frac{1}{8}$ inches ; find the distance in miles and draw a plain scale.

(*Punjab Univ., Inter., Supp. 1932 and 1933*)

**16.** What is a map ? How does it differ from a picture or diagram ? Give a brief description of the various types of maps that you may have seen. (*Punjab Univ., April 1942*)

# CHAPTER II

## REPRESENTATION OF RELIEF

**10.** The uneven nature of the ground, known as its relief, is shown by indicating on the map the height and shape of various hill features. In order to be proficient in map-reading it is necessary to have a thorough knowledge of the various methods used to show these features.

The following methods are adopted for the representation of hill features :—

(1) Contours.
(2) Form-lines.
(3) Hachures.
(4) Hill-shading.
(5) Contours and Hachures.
(6) Contours and Hill-shading.
(7) Layer Tints.

These methods are not suitable for atlas maps because of their scale.

**11. Contours.** A *Contour* is defined as the representation on a map of an imaginary line joining all immediately adjacent points which are of the same height above mean sea-level and at given vertical interval apart.

If you walk along the side of a hill taking care neither to go up nor down, your path is a *contour line.*

Thus a line an the map, joining all points at a height of 200 feet above sea-level, is called the 200-feet contour.

The vertical distance between any two successive contours is called the *Vertical Interval*, usually abbreviated as V.I. The vertical interval for any given map ordinarily is constant and is stated in feet. The contour lines are drawn at a given vertical interval apart. Thus, if the vertical interval of a map is 100 feet, the contours will be drawn at 100, 200, 300,......feet apart.

Two terms are frequently used in connection with contours: Vertical Interval and Horizontal Equivalent.

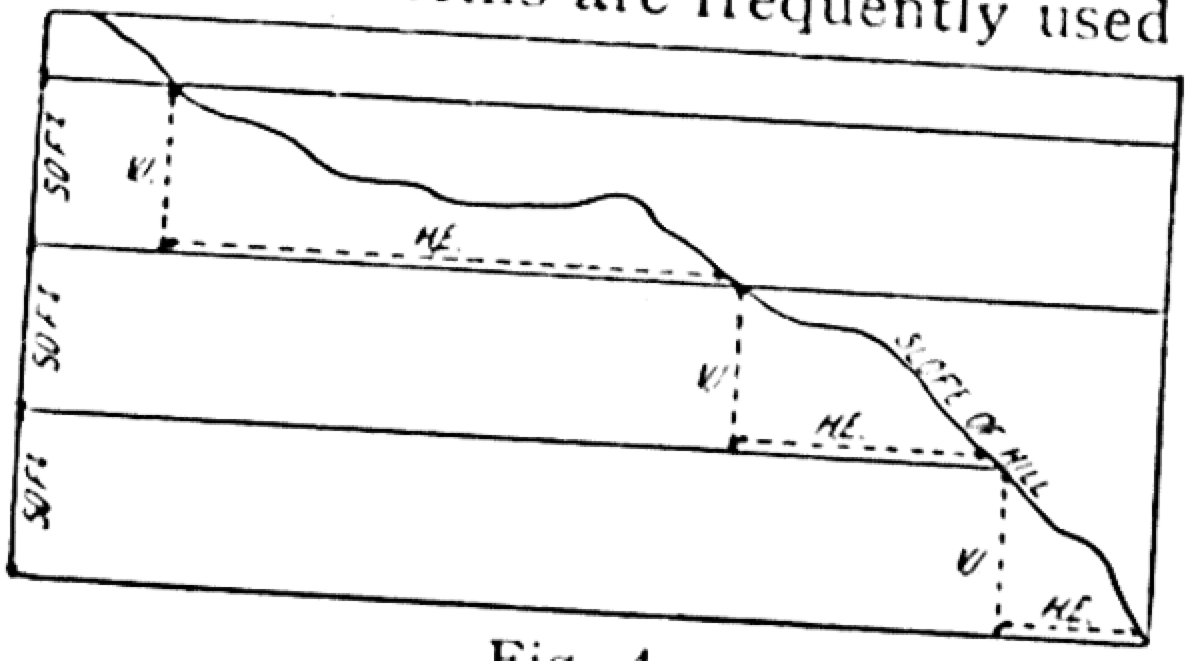


Fig. 4.

The *Vertical Interval* (written V. I.) is the difference in height between two successive contours. The V.I. is usually stated in *feet.* The V. I. is constant for any given map except in cases where many altitudes are shown, when the contours for the higher ground become very close together.

The *Horizontal Equivalent* (written H. E.) is the horizontal distance between two successive contour lines.

The H. E. is always expressed in *yards*, and it varies all over the map. It is small for steep slopes, increasing in value as the slopes become gradual.

**Experiment.** Knock off the pipe of a glass-funnel and place it on a table with its wide mouth downward. Draw parallel lines round the funnel at intervals of half-an-inch. When looked from above, the lines will appear as concentric circles ;, when transferred to paper as they appear from above, these circles will be the contours.

Let us imagine an island with two hills one 300 feet and the other 200 feet above sea-level; the two hills are connected by a narrow part called the "Saddle," a little over 100 feet. If the level of water rose a hundred feet the island would be smaller but its shape would remain about the same. A further rise of water would cover the saddle and the two hills would be converted into two islands. A further rise of 100 feet would leave only one hill standing 100 feet above the level of water. The three coast-lines in position will give an idea of the contours of the island drawn at intervals of 100 feet.

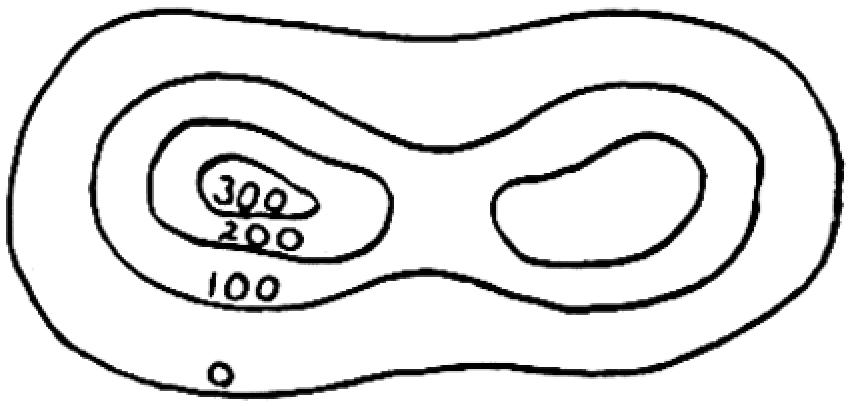


Fig. 5.

Consider a hill, whose one side is steeper than the other. A model made of plasticine, modelling clay or gelatine* would serve admirably for this purpose. Draw lines as in the above experiment. These lines when viewed from the top will appear close together on the steep side and wide apart on the gentle-slope side.

Hence—

*When contour lines are close together, they show a steep slope but when they are some distance apart they show a gentle or more gradual slope.*

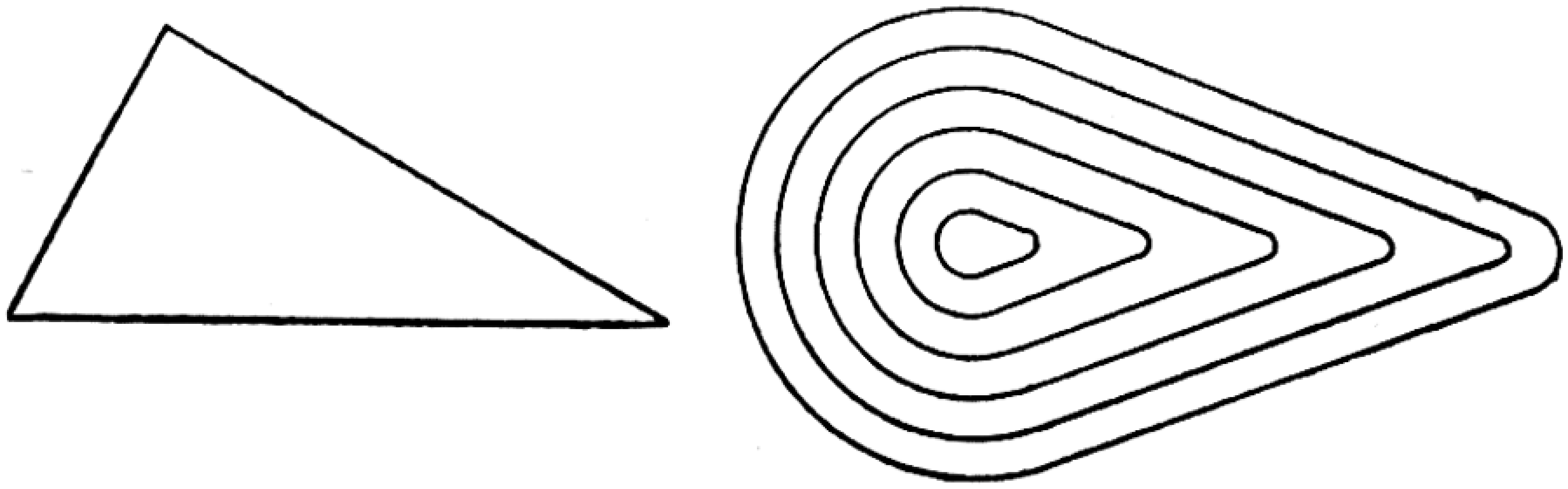


Fig. 6.

Hills and mountains do not have straight sides. It will be necessary to study a few irregular slopes as shown in Fig. 7. Study the various features and their contours carefully.

Note that the slope is

(i) *uniform* when the contours are spaced evenly.

---

* Pour hot water over gelatine and let it set in a few hours. When firm it can be cut with a knife easily to the proper shape.

(ii) *convex* when the space between the contours decreases towards the lower ground.

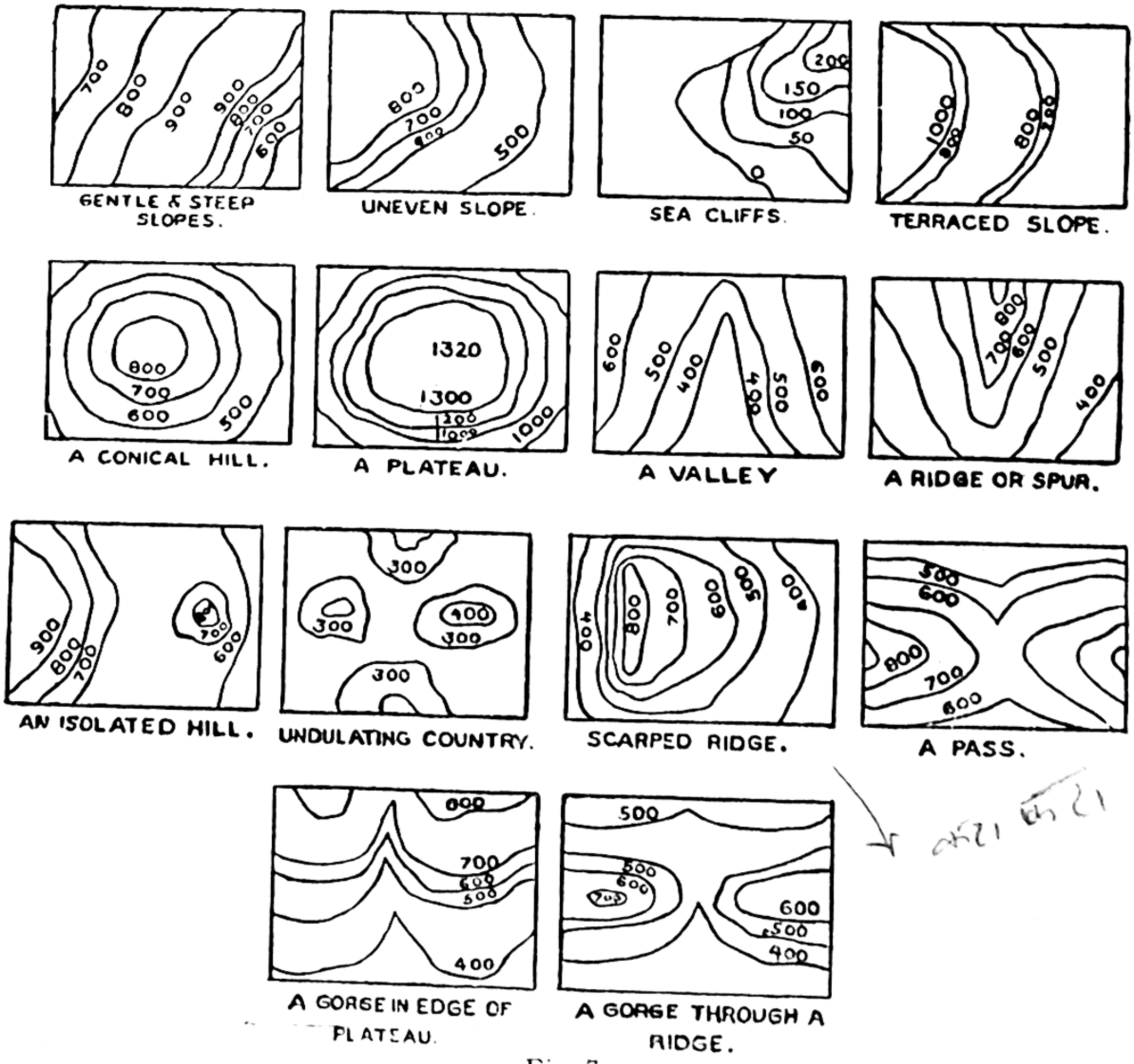
(iii) *concave* when the space between the contours increases towards the lower ground.

(iv) *undulating* when the above types are combined together.

**12. Points to be remembered in studying Contours.** (1) Contours are close together on steep ground and are far apart on gently sloping ground.

(2) A small ring, with no contour inside it indicates a peak or summit. A small triangle with a figure inside the ring denotes the actual summit.

(3) The contours both of isolated peaks and of lakes surrounded by higher ground on all sides are concentric curves, the difference being that in the case of peaks, heights increase towards the centre, while in the case of lakes, they decrease towards the centre.



GENTLE & STEEP SLOPES. UNEVEN SLOPE. SEA CLIFFS. TERRACED SLOPE. A CONICAL HILL. A PLATEAU. A VALLEY. A RIDGE OR SPUR. AN ISOLATED HILL. UNDULATING COUNTRY. SCARPED RIDGE. A PASS. A GORGE IN EDGE OF PLATEAU. A GORGE THROUGH A RIDGE.

Fig. 7.

(4) Both valleys and spurs are represented by V-shaped contours the difference being that in the case of a valley the angles of the V's point towards the higher ground, but in the case of a spur they point towards the lower ground.

The angles are close together in steep valleys and wide apart in gently sloping valleys.

(5) Rivers flow only in valleys, connecting the angles of the V's.

(6) Contour lines must be drawn as continuous and not broken lines. They should be differentiated from other lines on the map by using a coloured ink usually red or brown. When there is a large number of contour lines, it is useful to mark every 5th or 10th line slightly thicker than the others.

(7) This is the most important point to remember. *Show the figures on that side of the contour line on which the ground is rising*, *i.e.*, the figures must always be above the contour line *as regards slope*, even though this may involve some figures being upside down when the map is viewed with the north at the top.

(8) Figures should be shown in continuous lines from top to bottom and must not be scattered about.

**13. Valley Contours.** A valley is a depression or low-lying tract of land between two hills or mountains and often traversed by a stream or a river, which carries off the drainage of the higher ground.

The contours of a valley are marked by V-shaped contours. Note that the points of the V point to the high land.

The points of V's mark the lowest part of the valley, hence rivers must cross the contours at the points of V's.

The contours are paired on opposite sides of the river. No river can run between two contours of different heights, *i.e.*, if the nearest contour on one side of the river is 400 feet, the one on the other side will also be 400 feet.

Ordinarily rivers rise at or near the heads of their valleys, unless otherwise stated.

Rivers on level land meander a good deal.

NOTE.—A **Spur** is an extension of high land towards the low-land. The spur is also marked by V-shaped contours, but in the case of a spur the points of V's point towards low ground.

**14. Form-lines.** On small-scale maps, the heights are sometimes represented by form-lines. They are contours, not figured. They show the general pattern of the ground and not the actual heights. These lines are broken.

NOTE.—Broken and dotted lines are also used for boundaries, paths, etc., but in that case the spacing is uniform, *i.e.*, the space between the lines is equal to the lines themselves but in form-lines the spacing is not uniform.]

Sometimes numbers may be inserted to show the heights of peaks and summits, etc.

**15. Hachures.** Hachures are short, disconnected lines, drawn down the slopes, in the direction of the steepest gradient. When the slope is steep, they are made heavy and close together; when the slope is gentle, they are made lighter and farther apart. Flat ground is left unshaded.

Hachures are drawn in the *direction* of the slope; thus they represent the direction in which water would flow over the surface if allowed to run freely. They are drawn at right angles to the direction of the contours at any point.

The *advantages* of hachured maps are :—

(1) They convey at a glance a general idea of relative steepness.

(2) In a contoured map when the vertical interval is large, the addition of hachures is valuable in showing minor features, which ordinarily are not shown by contours.

Their chief *drawback* is that they obscure other details and interfere with the legibility of the lettering on the map. This defect is now obviated by doing the hachures in colour.

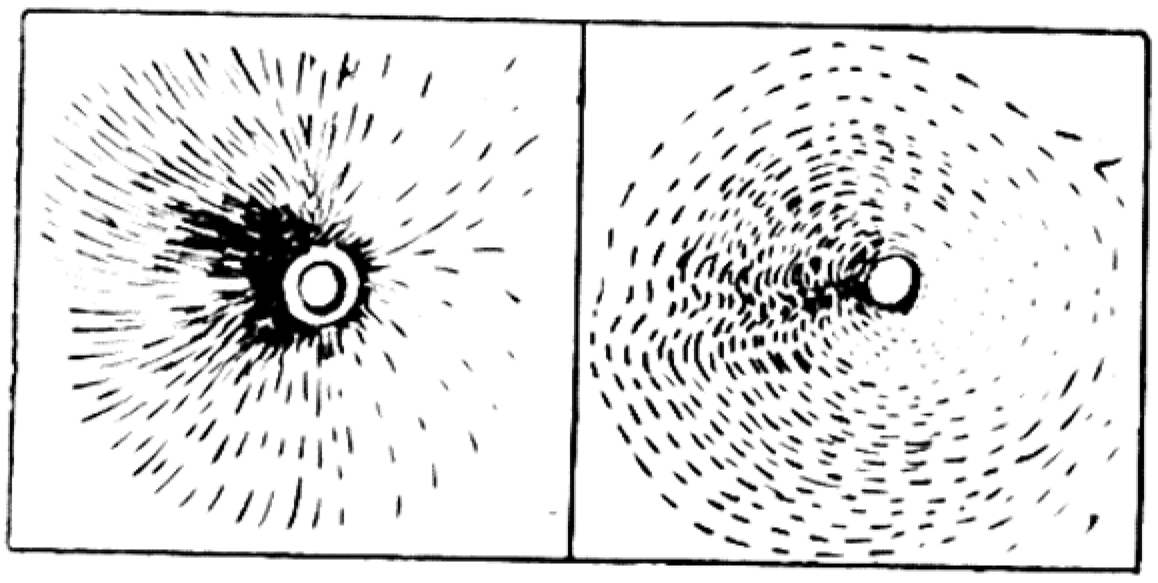


Fig. 8.

In Fig. 8 form-lines are shown on the right and hachures on the left for a hill whose right-hand slope is gentle and left-hand slope is steep.

**16. Hill-shading.** In hill-shading the same effect as that in hachures is produced by a smooth graduated wash of colour or by pencil shading. This may be best explained by imagining that a light *vertically* over the country causes illumination which decreases in intensity the steeper the slope. Both sides of a hill therefore would be dark, and the summit and the valleys would be left white on the map.

In *oblique* hachuring or hill-shading, the shade is made darker on the sides of the slopes facing away from north-west. The effect produced is very much like the shadow cast by a light, situated in the north-west, falling obliquely on a relief model.

Hachures and hill-shading do not show exact heights, nor adequately the relative altitudes and the gradients. These methods are used for small-scale maps on which contours cannot be shown. Study a 10 miles=1" map of any hilly country.

**17. Contours and Hachures.** When the vertical interval of contours is a large one, contours are supplemented by hachures lightly shown in brown, which show the minor formations omitted by contours.

**18. Contours and Hill-shading.** Contours are sometimes supplemented by hill-shading. This method is adopted by the French 1/50,000 maps.

**19. Layer Tints.** Layers or tints of colour are used to denote all the land between any two named contours.

Blue is used for the sea, the shade increasing in strength in the following order as the depth increases :—

Very light blue
Light blue
Blue
Dark blue
Indigo.

Low-lying land is shown by the following colours in increasing order of height of land :—

Green (usually dull-green)
Light-green
Yellowish-green.

Highland is shown by the following shades of colour in increasing order of height :—

Light brown
Brown
Dark brown
Reddish brown
Crimson red

High glaciated areas are shown in white—usually with a tinge of blue.

This method is growing increasingly popular, as a vivid picture of the distribution of high and low ground can be seen at a glance. There is, however, one objection, that when there is a considerable range in altitude, each change of colour interval cannot be distinctly shown.

NOTE 1.—If crayons are used, colouring should be done after all other details have been inserted ; with water-colour, the colouring should be done before filling in the other details.

NOTE 2.—A map is usually judged by its appearance. Colouring must be done very carefully. It must be smooth, and without any spots or patches.

**20. Types of Hill Features.** Fig. 9 shows the hill features in a bird's-eye view and also a corresponding contoured map, which should be carefully studied.

**Mountain.** A mountain is an elevation usually more than 3,000 feet high.

**Hill.** An eminence less than 3,000 feet in height.

A **Plateau** is a tract of high level ground. It is fairly broad as compared with its length.

A **Ridge** is a long, narrow and fairly sharp-edged strip of high land.

**Crest** or **Brow** is that part of the summit of a hill where the steep side changes to the flatter top.

**Saddle, Col,** or **Neck** is the land connecting two hills or mountains. Passes are formed across saddles. It is a depression through which the ridge-line passes to connect the summits of a chain of hills.

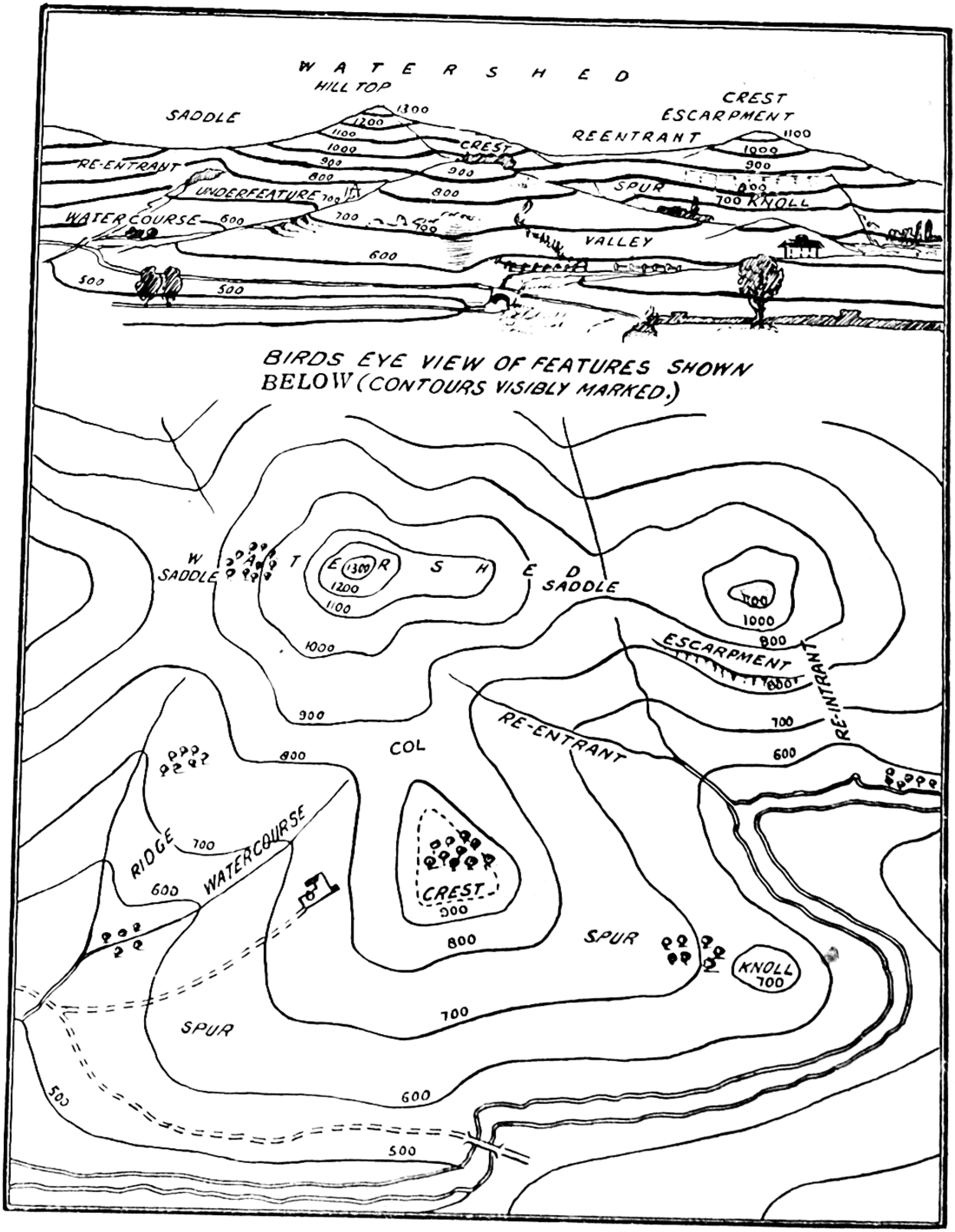

WATERSHED
HILL TOP
SADDLE
1300
1200
1100
1000
900
800
CREST
ESCARPMENT
REENTRANT
1100
1000
900
800
700 KNOLL
RE-ENTRANT
CREST
900
800
SPUR
UNDERFEATURE 700
WATERCOURSE 600
700
VALLEY
600
500
500
BIRDS EYE VIEW OF FEATURES SHOWN BELOW (CONTOURS VISIBLY MARKED.)
W A T E R S H E D
SADDLE
1300
1200
1100
1000
SADDLE
700
1000
800
ESCARPMENT
800
RE-INTRANT
900
COL
RE-ENTRANT
700
600
800
RIDGE
700
WATERCOURSE
600
CREST
900
800
SPUR
KNOLL 700
700
SPUR
600
500
500

Fig. 9.

A **Watershed** or **water-parting** or **divide** is the high ground from which the water falls on either side to two distinct drainage systems.

A **Spur** or **Bluff** is a tongue of land projecting from high ground into lower ground. It is shown by contours with points of V's pointing to lower ground.

A **Shoulder** is a broad, flattened spur with steeper slopes above and below it.

A **Rs-entrant** is a depression in the side of a hill or sloping ground. All valleys are re-entrants but all re-entrants need not be valleys.

A **Valley** is the part of the ground lying between two slopes meeting at their bases.

**Watercourse** defines the lowest line of a valley along which water runs.

**Basin** is the area of a country drained by a river and its tributaries.

A **Gorge** is a narrow opening between hills with steep precipitous sides.

Spur

A **Knoll** is a small hill or mound.

An **Escarpment** is an extended line of cliffs.

**21. Sections and Profiles.** A section or profile from a contoured map gives us a definite picture of the relief along a line. With suitable modifications it could be made to illustrate features which otherwise would remain hidden. A *section* is the outline of the intersection of the ground by a vertical plane, or in other words is the surface formed when a solid is cut by a plane. When an apple is cut by a knife into two equal pieces, the freshly-cut surface of each half is a section.

A section has two scales :—

(*i*) The *horizontal* scale—This is always the same as that of the map from which it is drawn.

(*ii*) The *vertical* scale.—This may be the same or some multiple of the horizontal scale.

Use a graph paper for drawing sections. Fig. 10 illustrates how a section can be obtained along MN. Draw perpendiculars from each point where the contour lines intersect the line MN to the equivalent height marked on the vertical scale. In this case the horizontal line is of the same length as MN. Join the various points thus obtained by a smooth curve.

If a section along a diagonal line say PQ is required; place a strip of paper along PQ. Mark the intersection of the contours along the edge of the paper, and transfer them to the new horizontal line drawn equal to PQ. Draw perpendiculars as before and complete the profile.

**22. Intervisibility.** An important problem in map-work is to find out whether two points are intervisible or what is the area of the ground not visible (called "dead ground") from any given point.

If the solpes are examined, visibility can be deduced from the contours by drawing a section along the points concerned. When the slopes are convex, the points are not mutually visible; if the slopes are concave the points are mutually visible unless prevented by some minor feature or any other obstruction.

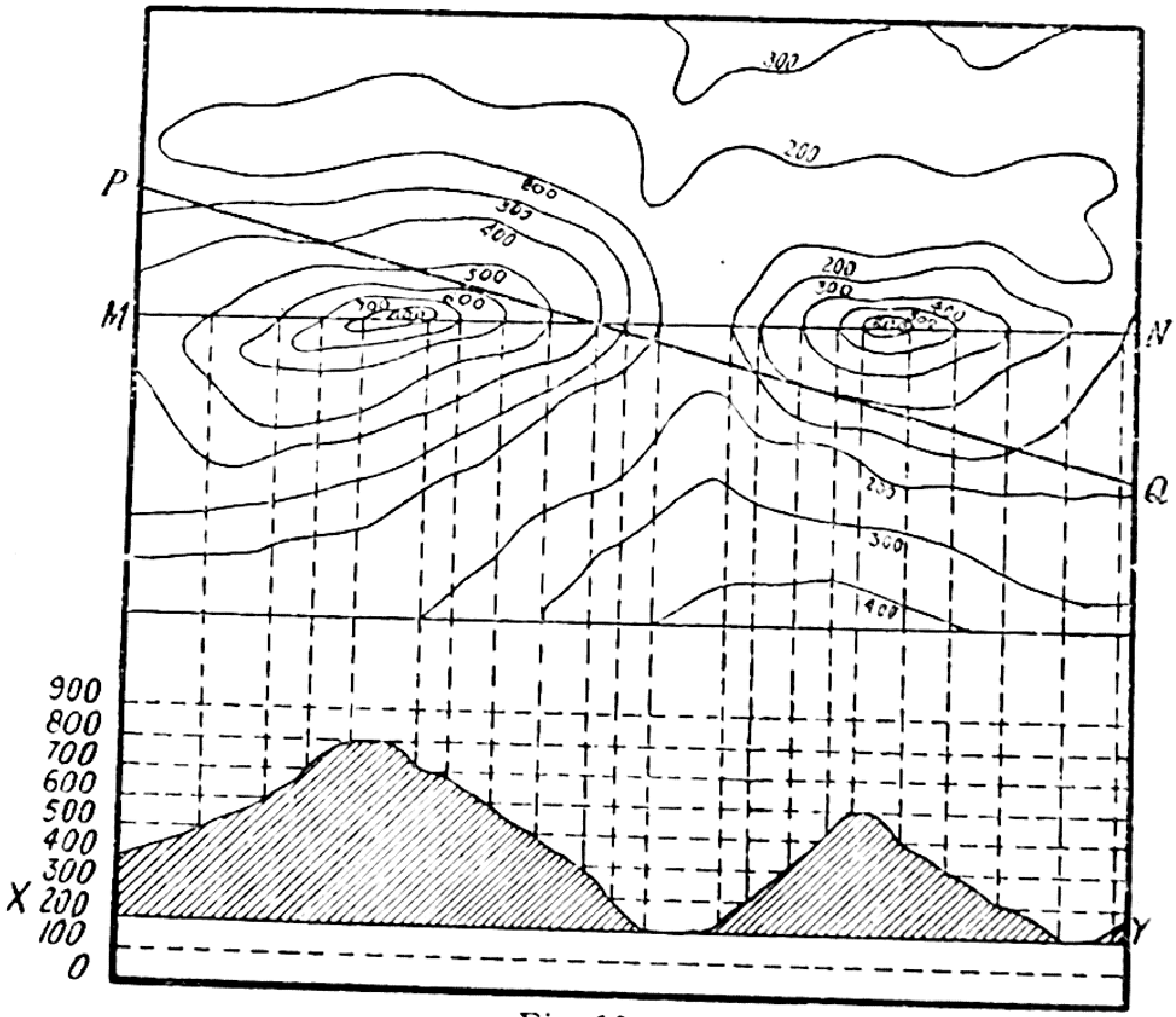


Fig. 10.

## EXERCISES

1. Draw contour maps to show the following features :—
   - (i) A hill-slope well dissected with streams.
   - (ii) A scarp facing south rising to 800 ft. cut through by a river (200 ft.) and two gaps at 500 ft.
   - (iii) A flat-bottomed valley in montainous country with a river flowing at one side of the valley.
   - (iv) An east-west gorge connecting two broad flat valley-bottoms.
   - (v) A spur 700 ft. high extending south-westwards from a plateau into a broad valley.
   - (vi) A south-flowing river emerging from a gorge into a wide flat-bottomed valley whose western side is steep, other slope being gentle.
   - (vii) A highland mass rising to 1,500 ft. to the south-east of which are scarps. (800 ft.) facing north-west and broken through by rivers.
2. What advantages have contours over other methods of showing relief ?
3. Illustrate by contours the various types of slopes.
4. How is a valley recognized on a contoured map? How does it differ from a sloping ridge ? Illustrate by diagrams.
5. Draw simple contour, sketch-maps to represent the following land forms :—
   - (a) a dissected plateau
   - (b) a mountain stream with a few tributries and a lake.
   - (c) a ria type of coast or a fiord type of coast. (*Punjab Univ., Inter., Sept. 1939*)
6. Show by means of contours the following :—a U-shaped valley, a V-shaped valley, a conical hill, a pass in high mountain ranges, a ridge with steep slopes.

(*Muslim Univ., Aligarh, Inter., 1939*)

# CHAPTER III

## MAP READING

**23. Conventional Signs used in Survey Maps.** In order to be able to read a map legibly, it is necessary to use distinctive symbols for various features, and use different types of letters for different purposes. These symbols are known as *conventional signs*. The conventional signs used in cartography are such as will convey all the information possible compatible with the general clearness and legibility of the map. Practice in drawing these signs is essential.

They differ for various types of maps; for instance more symbols are used for 1 inch=1 mile map than for 1:1,000,000 map; symbols for the same feature are not always of the same size or type on both the maps. The conventional signs vary in every country but the general principle is the same. The conventional signs are shown on what is termed a *characteristic sheet**: explanatory diagrams are usually shown on the margin of Survey maps.

A good symbol is one which can be recognized without a legend.

If the real proportions were used, many symbols would be microscopic, hence the term conventional signs. For instance on a map of 1 to 1 million, a 20 feet wide road will show a thin line but topographic sheets show roads by double lines about $\frac{1}{40}$th inch apart.

The symbols of a map may be divided into four groups :—

(1) Relief features (hypsography)—usually by various shades of brown.
(2) Water features (hydrography)—indicated by blue.
(3) Vegetation—shown in green.
(4) Man-made features (cultural)—usually shown in black and red.

**Roads.** Roads are shown by parallel lines in red. Fenced roads are shown by continuous lines, and unfenced by dotted lines. First class roads have two thick lines; second class, one thick line and one thin line; third class, two thin lines; and fourth class or unmetalled, two thin lines *closely* spaced. Bridle paths and foot-paths are shown by broken lines in red.

**Milestones** are marked by a numeral giving the distance.

**Railways** are shown in black by double lines with short ticks between; for a double line the alternate spaces are solid black.

**Rivers** are shown by a double line with water lining. They are tinted blue on coloured maps. Rivers less than 15 feet in width are shown by a single line.

**Canals** are shown by double parallel lines in blue.

**Marshes** are shown by horizontal lines with little ticks above.

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* Characteristic sheet of conventional signs can be had from the Survey of India Office, Calcutta.

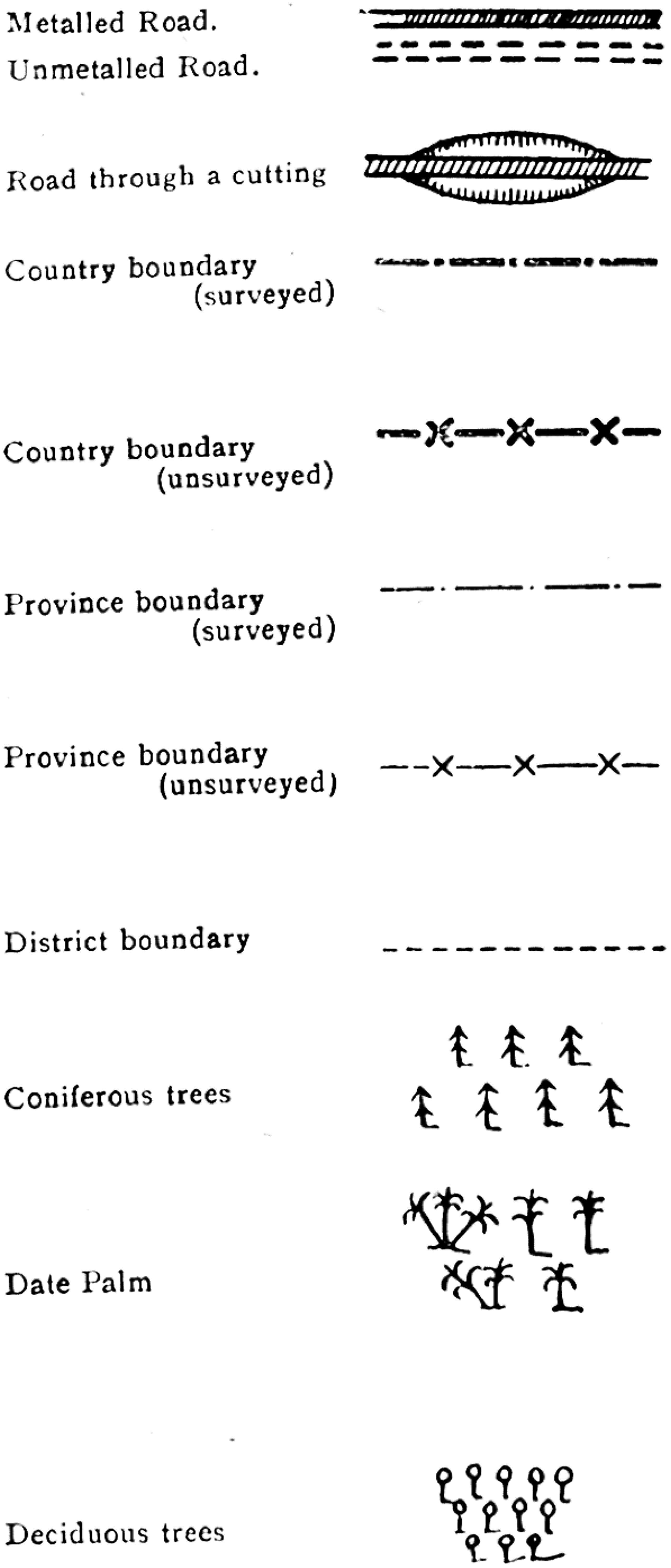

Metalled Road.
Unmetalled Road.
Road through a cutting
Country boundary (surveyed)
Country boundary (unsurveyed)
Province boundary (surveyed)
Province boundary (unsurveyed)
District boundary
Coniferous trees
Date Palm
Deciduous trees

Fig. 11 (*a*)

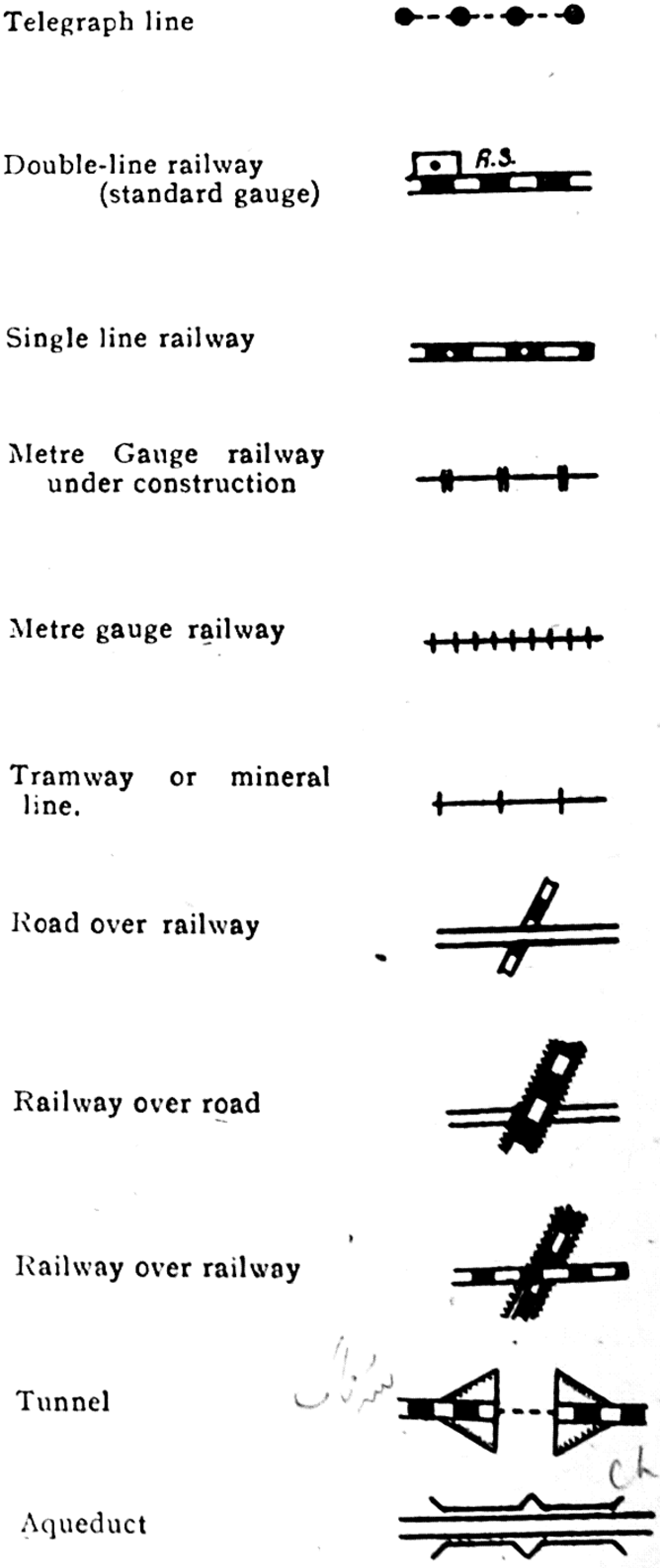


Fig. 11 (*b*)

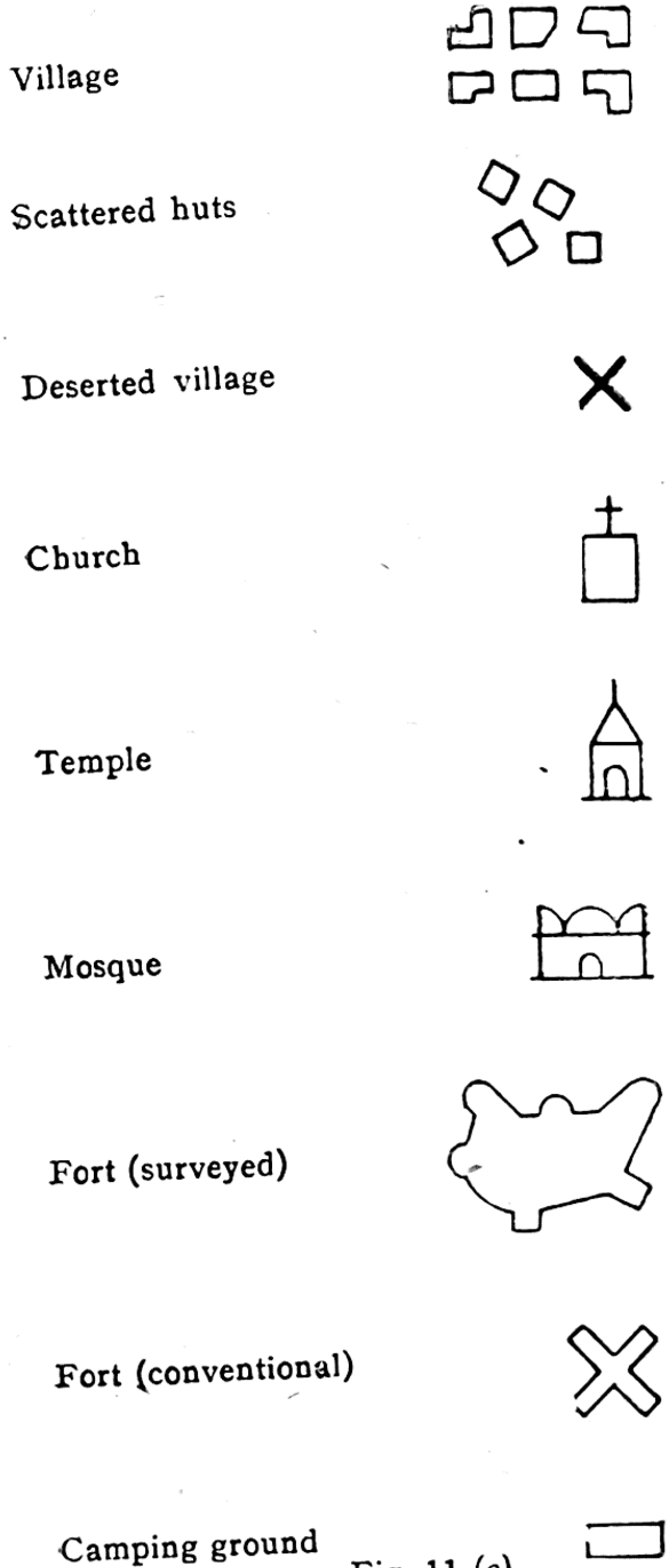


Fig. 11 (c)

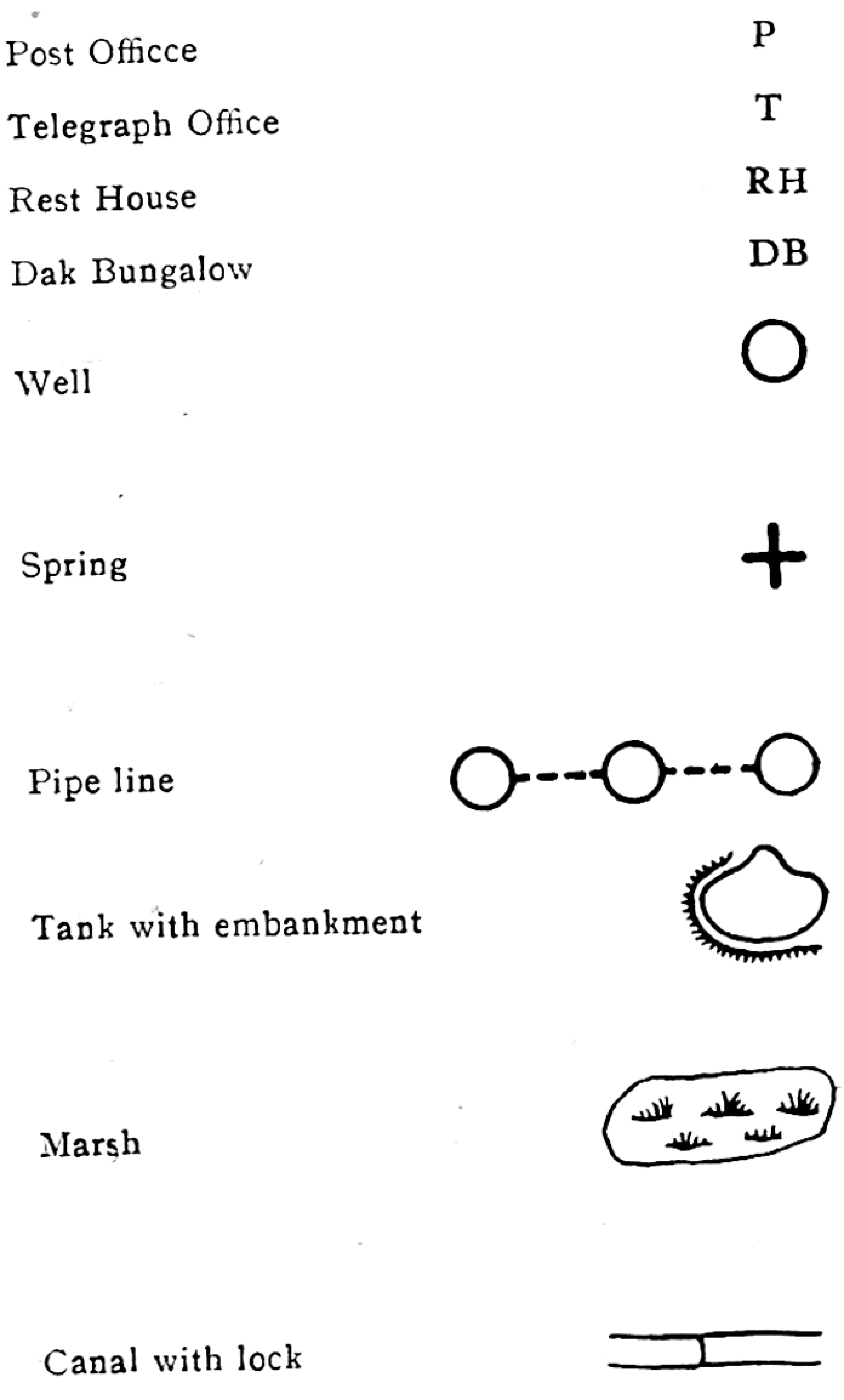


Fig. 11 (d)

NOTE.—The symbols in Fig. 11 have been exaggerated in size. The student is advised to study these from a characteristic sheet, using a lens, if necessary.

**Pasture** ground is shown by minute black ticks arranged in series.
**Woods** are shown by trees and tinted green on coloured maps.
**Orchards** are shown by small tree signs symmetrically arranged.

**Parks** are shown by a stippling of black dots.

**Quarries** are shown by a dark line from which spring short lines.

**Buildings** are marked solid black or red.

**Boundaries.** Boundary between provinces is shown by a thick peck-line, and that between districts by a dotted line.

It is not possible to reproduce all the conventional signs from the characteristic sheet. These sheets may be easily obtained and the symbols used are self-explanatory. These should be carefully studied.

**24. Marginal Information.** The following information of a general character is always shown on the margin of all maps, which must be carefully studied :—

(1) Scale, shown at the foot of the map.

(2) North point, shown on the top right-hand side, and magnetic variation.

(3) Altitudes, given in feet ; heights shown by layer-tints or contours.

(4) Reference numbers.

(5) Legend (or Symbols) giving an abstract of more important conventional signs.

(6) Date of publication.

**25. Proficiency in Map Reading.** The student is advised to purchase Survey of India sheets (Scale 1/M, *i.e.*, 1 inch to 1 million inches and one inch to one mile) of any familiar district and also the characteristic sheet giving the conventional signs. These maps can be had from the Map Record and Issue Office, Survey of India, Calcutta,

These maps should be studied systematically on the following lines.—

Remember that the interpretation should be from the evidence of the map alone. The material presented in the map should be collected and sorted. Then the sorted material should be classified in illustration of some aspect of Physical Geography or Human Geography or of both.

(1) **Preliminary Statement.** Describe the marginal information as given above. Note the scale and calculate the area to give you an idea as to how much country is shown by the map.

(2) **Cartographic Methods Used.** Study the characteristic sheet appended to the map, the range of information available and the scope of symbolism. Classify in groups as explained on page 17 and illustrate.

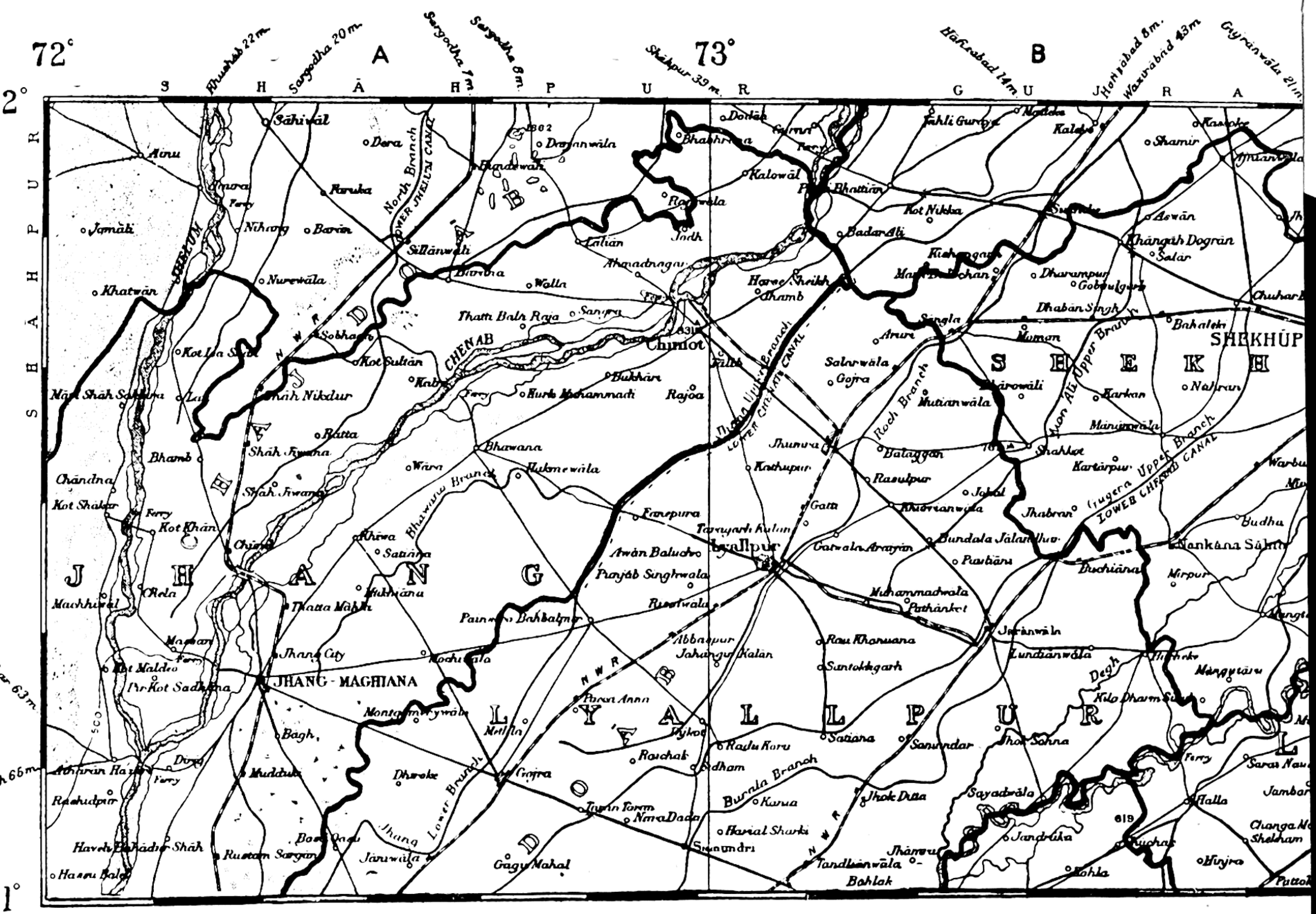
(3) **Physical Geography.** Give a general survey of relief and drainage. Draw a simplified sktech showing the relief features only (omitting minor details). Divide the area into two or three zones based on relief and study each zone under the following heads :—

(*i*) An analysis of relief—*i.e.*, slopes, heights, waterfalls, watershed, high ground, low-lying valleys, etc.

(*ii*) River work ; stage of development.

(*iii*) Glacial phenomena—erosion and deposition.

(*iv*) Coastal features—a separate physiographic unit—the work of sea as an agent of erosion and deposition.



[To face p

SURVEY OF INDIA SHEET SCALE 1/M

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(4) **Vegetation.** Discuss the type of natural vegetation.

(5) **Human Geography.** Analyse and discuss the human response to physical environment. Draw a sketch of communications and human settlements.

Discuss the communications; the class, type and the direction in which they run.

Discuss the cultural settlements,—villages, towns, nodal towns, boundary lines and other man-made features affecting human settlements.

(6) **Conclusion.** Divide the area into natural regions bearing in mind all previous deductions as to relief, vegetation, considered now in relation to human activities.

The most profitable way of studying a survey map is to select a map of an area well-known to you and study it in conjunction with practical work, *i.e.*, fairly detailed examination with a view to systematic geographical description.

## EXERCISES

Select from the Survey of India 1/M and one-inch survey sheets examples of maps representing different types of country and analyse them on lines suggested by the following questions :—

1. Reduce the scale and draw a sketch-map showing the relief and drainage. Suggest possible divisions into physiographic regions justifying such division.

2. On a reduced sketch-map show the distribution of villages and towns. Discuss the general distribution of population.

3. Explain how far the area is served by and account for the occurrence of different types of roads.

4. On a reduced sketch show the routes and towns and explain how far the sites of the towns and routes are influenced by physical features.

5. Identify and reproduce on a larger scale the following features from the given map.—
a water-shed ; a hanging valley ; col ; a spur ; a scarped slope ; a conical hill ; a plateau ; a ridge.

---

6. Discuss the methods of showing (*a*) relief, (*b*) vegetation, (*c*) communications, (*d*) cultural settlements as shows on the given sheet.

7. Describe and illustrate the cartogaphical methods employed on the Survey of India maps on a scale of 1 : 1,000,000 which you may have studied. (*Punjab Univ. Inter.*, *1934*)

8. Describe the important topographical features of any selected Survey of India sheet (Scale 1 : 1,000,000) studied by you. (*Punjab Univ., Inter.*, *1935*)

9. Write a systematic geographical account of any Survey of India sheet (Scale 1 : 1,000,000) studied by you. (*Punjab Univ., 1936, 1937 & Supp. 1937*)

# CHAPTER IV

## MAP DRAWING FROM DATA

**26. Map Construction.** A description of a piece of land can be easily translated into a map if contouring and conventional signs used in map-work have been thoroughly understood.

In order to draw a contoured map note the following :—

(1) Read carefully the data supplied several times and fix the major features in the mind in their relative positions.

(2) Draw a rough sketch and write down the *names* of the features in their correct positions.

(3) Select a convenient scale and draw the border of the map in pencil bearing in mind the extent of the country to be shown.

(4) Draw the lowest and the highest contour lines.

(5) Insert the rivers and other major features.

(6) Select a suitable vertical interval and draw in all the contours now bearing in mind the shape these contours must take with reference to features already indicated, *e.g.*, when contour lines cut rivers, the points of V's should point to high ground, and in case of spurs to lower ground.

(7) Insert other features and means of communications and cultural settlements.

(8) Check the sketch and see if all the features required in the data are shown therein, and nothing of an impossible nature (*e.g.*, a river flowing uphill) has been inserted. ***Do not insert features not required in the data supplied.***

(9) Note that the contour lines must either form closed chains or run to the edge of the map. Do not crowd the map with contours to obscure other features ; nor should the contours be too few. Strike at a mean consistent with data and neatness of the whole sketch.

(10) Ink the map showing the contours in brown or red, and using conventional signs for various features. Label the necessary features etc.

(11) Draw the border ; scale ; show north, and give a key to all the symbols used.

**Example.** *Construct a map showing by means of contour lines at 100 ft. intervals the following features :—*

*A long ridge runs from west to east. Its crest is on the average over 600 ft. in height, but it is notched in three places by gaps and is completely broken through by a river which is flowing from south to north. The ridge on the northern side sinks gradually to a marshy plain. The slope on the southern side is steep in its upper portion and then becomes more gradual.*

*The country to the south of the ridge is broken, undulating and wooded. Near the point at which the river begins to cut through the ridge on its southern side, is a town with a church, situated on an isolated hill. A main road and a railway pass through the river valley, while secondary roads make use of the other gaps.* (See Fig. 12).

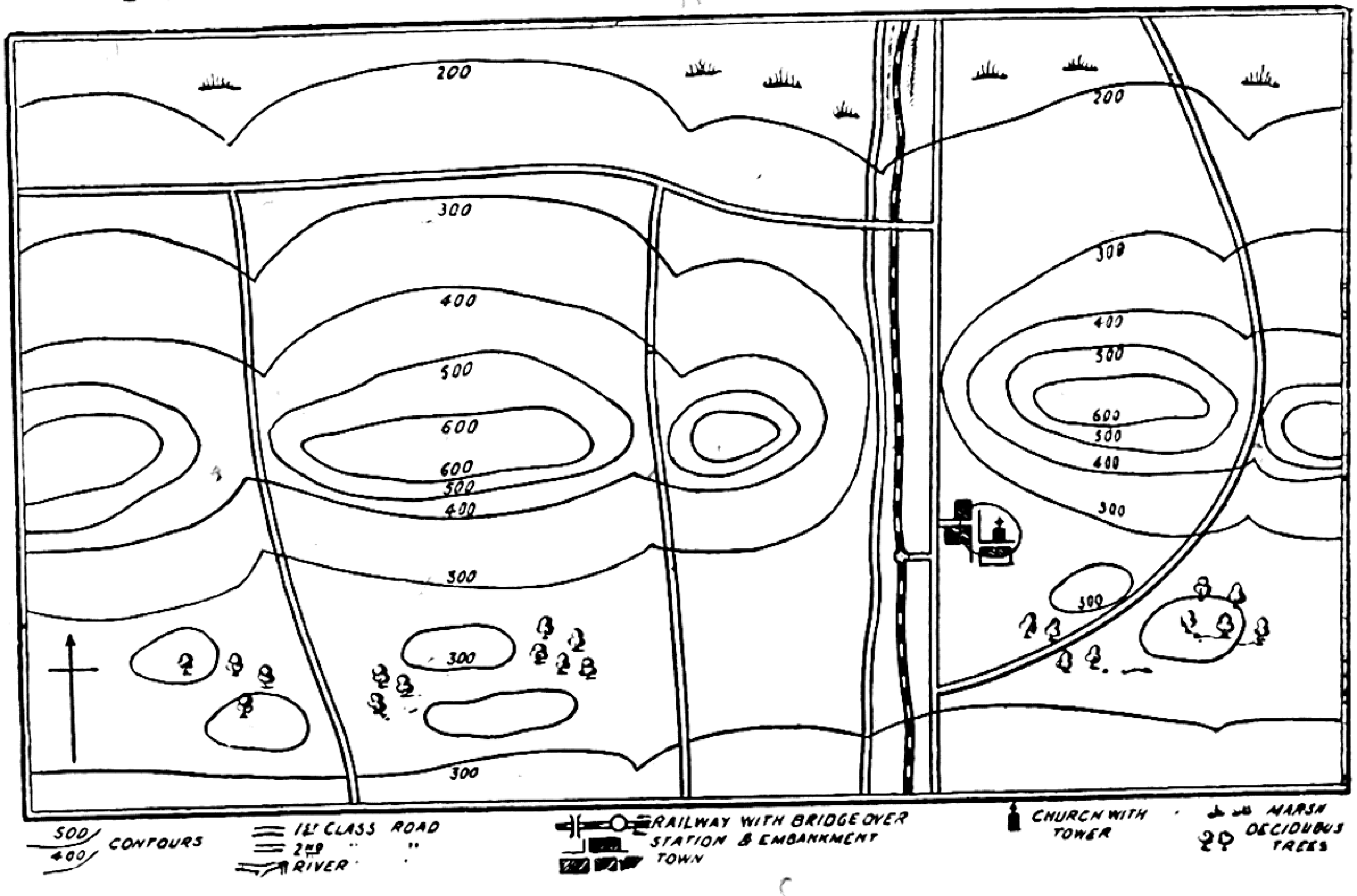


Fig. 12.

**27. Copying Maps.** A map may be copied on tracing paper by placing it over the original. It is a saving of time to trace direct in ink.

**28. Enlarging and Reducing Maps.** Map enlargement, which is very simple in its principle, is of considerable importance in modern warfare. Small-scale maps are supplied to the military staff. The minor features, which may be of military importance, are not marked. Hence an enlargement of the small-scale map is made and the additional information is completed on the site as may be necessary. The following methods are commonly used :—

(1) **The Method of Squares.** Draw a network of unit squares over the map to be copied, reduced or enlarged. Prepare another network of squares on a blank drawing paper, with their sides reduced or enlarged by the factor chosen. Insert the detail by eye, square by square.

The greater the number of squares, the more accurate will be the enlargement or reduction.

(2) **The Method of Similar Triangles.** This method which is much simpler than the above is used for routes etc. From any convenient points, lines are drawn to the salient points of the original route. The ends of the route are joined to form a triangle. If it is desired to reduce the map, another point on the side nearer to the first point, proportional to the required scale is taken and the route is then sketched in. If an enlargement is required the second point is taken on the side farther to the first point on producing the sides of the triangle.

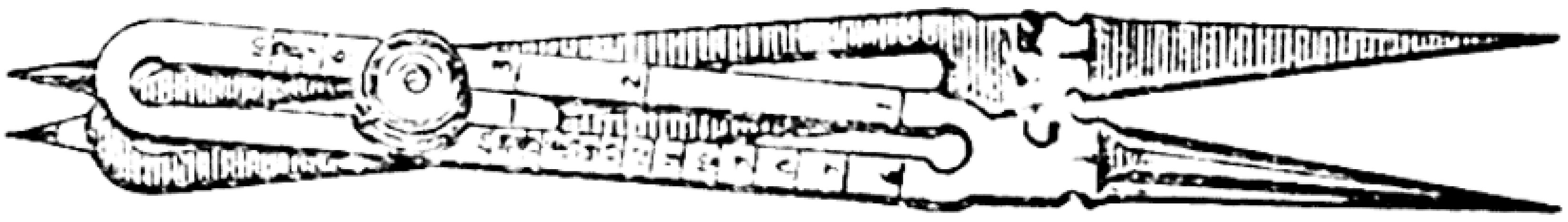


Fig. 13.

*The Proportional Compass*, a simple instrument based upon the above principle will be readily understood by using it.

**29. Lettering.** A good map may be spoilt by careless lettering. It is necessary that all names on the maps must be clear, legible and neat in appearance. Lettering is a tedious task hence no attempt must be made to make it very artistic and only such style should be adopted as should be neat and fairly rapid to execute. The following points must be borne in mind :—

(1) Select a style which approximates to your natural handwriting.

(2) The spacing between letters must *appear* even ; the shape and size of the letters must be uniform ; *e.g.*, the space between two O's is less than that between two l's.

(3) Use a stiff and broad-pointed nib. A springy nib is not good for lettering. Do not use a fountain-pen.

(4) For most lettering there are two styles :—the Roman (or the upright) and the Italic (or slant lettering), *e.g.*, LAHORE ; *LAHORE*.

Land features are shown usually in Roman and water features in Italic styles.

(5) Do not omit to finish the map with a border, compass rose etc. Ornamentation must be avoided.

Remember that.—

By the **style** of your letters, you differentiate the various features, *e.g.*, mountains and rivers.

By the **size** of your letters you express the importance of these features.

By the **spacing** between the letters you express their extent,

All letters must read in the *same* direction.

## EXERCISES

1. Draw a sketch map of a village with a post and telegraph office, a church with spire, and an inn. A main route passess through it and two foot-paths cross the main route in the village.

2. On a scale of 1 mile=1" draw a contour map of an island 4 by 2 miles, with the ground rising to a hill whose summit is a mile from the eastern shore and is 800 ft. high. All slopes are concave. [Vertical interval 50 ft.]

3. An island $6 \times 4$ miles has two hills, one 400 ft. and the other 200 ft. high. Slopes below 200 ft. are gentle; those above 200 ft. are steep. Insert a river and a road across the island. Draw a contour map on a scale 1 mile = 1″ and V.I. 50 ft.

4. Using a suitable scale draw a map having an area of 150 sq. miles. By means of contour lines represent the following features :—

A mountain range runs from S.W. to N.E., rises to a height of 2,000 ft., slopes steeply to the S.E. and more gently to the N.W. A stream rising on the N.W. slope runs N.W. into the sea after crossing a plain. Along the coast are sea cliffs over 300 ft. in height.

Make a section which will best show the character of the country.

5. Draw a contoured map showing the following features: A plateau about 1,000 ft. in average elevation terminates eastwards in a steep escarpment overlooking a low plain. To the west it sinks more gradually to the sea, but a ridge of high land connected with the plateau forms a bold promontory. Three streams which have excavated deep valleys in the plateau unite in a river which flows out south of the promontory. [V.I. 50 ft.]

6. Draw a contour map illustrating a deep river valley with hills rising 2,000 ft. on the right bank of the river and 4,000 ft. on the left bank, and crossed by a railway through mountain passes of not more than 500 ft. above sea level. (*Punjab Univ., Inter., April 1941*)

7. Draw a map illustrating the following features: A town lies in the centre of a plain about 100 miles square. The town is on a small island in the main stream of the plain, which drains westward. The town is at the head of navigation. The plain is at the focus of continental routes from the East and South. The sea is 50 miles from the town on the North and West, but the river course below the town is about 80 miles long. [Scale 16 miles = 1″.]

8. What is meant by a contour map? Draw one to show an island rising steeply on its eastern side, and gently on its western side, to the central highest point of 600 feet above sea-level. Insert a river valley terminating south in an estuary two miles long. Indicate the best route for a road across the island.

9. Reduce the map in Q. 8 to half the scale.

10. Enlarge the Red Sea from a map of Africa in your-atlas to double its scale.

11. On a scale of 1 ; 40,000 construct a plan of a village which extends 4 miles east and west and 3 miles north and south, showing huts, metalled and unmetalled roads, foot paths, lined and unlined wells, an unlined tank, a canal, a garden, arable and waste land, post and telegraph office and a railway station on a narrow-gauge line. (*Punjab Univ., Inter., 1933*)

12. Draw a contoured map of any area that you may have studied. Show lines of communication, flow of streams and human settlements.

Write a short geography of the area you have mapped. (*Punjab Univ., Inter., 1935*)

13. Draw a map of a small area that you may have studied. Show, by means of signs used on the Survey of India sheets, the main topographic features and facts of human geography. (*Punjab Univ., Inter., 1936*)

14. What is a contour? A rectangular area with its longer side east and west measures 18 miles by 7 miles. A mile south of the northern edge lies the crest of a mountain ridge of which the peaks reach between 800 and 900 feet. A spur is thrown off about seven miles from the eastern end of the range and descends irregularly to the south, falling to 300 feet at the southern edge of the area. The floors of the valley east and west of this spur are as low as 200 feet. Make a contoured sketch-map of the area on a scale of 1″ = 2 miles. (*Punjab Univ., Inter., Sept., 1941*)

# CHAPTER V

## STATISTICAL AND DISTRIBUTIONAL MAPS

30. Distributional maps show the centres of production of any commodity, usually stocks, crops, minerals, and the density of population. They help the geographer to study the cause and effect, say, of the density of population of any area or of the large scale production of any crop in any area. To complete our enquiry into the factors which control the distribution of any commodity, or of man, it is necessary to study the distributional maps in conjunction with physical and climatic maps. For instance, the sources of our wool supply depend upon the distribution of sheep, which depends on both physical features and climate. Sheep do not like much heat or damp, and in tropical regions they thrive only where the heat is modified by altitude.

31. **Stocks and Crops.** The following methods are used to represent stocks and crops on distributional maps :—

(1) *Writing the name of the commodity.* The name of the commodity is printed in capital letters or in rectangles across the area where the particular commodity is produced thus—RICE. This method is qualitative and does not give us any quantitative idea of the commodity produced. Thus the word RICE printed over the Ganges delta only shows us that rice is produced in Lower Bengal, but it does not convey any idea of the quantity of rice produced per acre per year or the total quantity produced in a year or in an average of five years. Moreover there may be stretches of unfavourable soil, in the same area where rice is not cultivated.

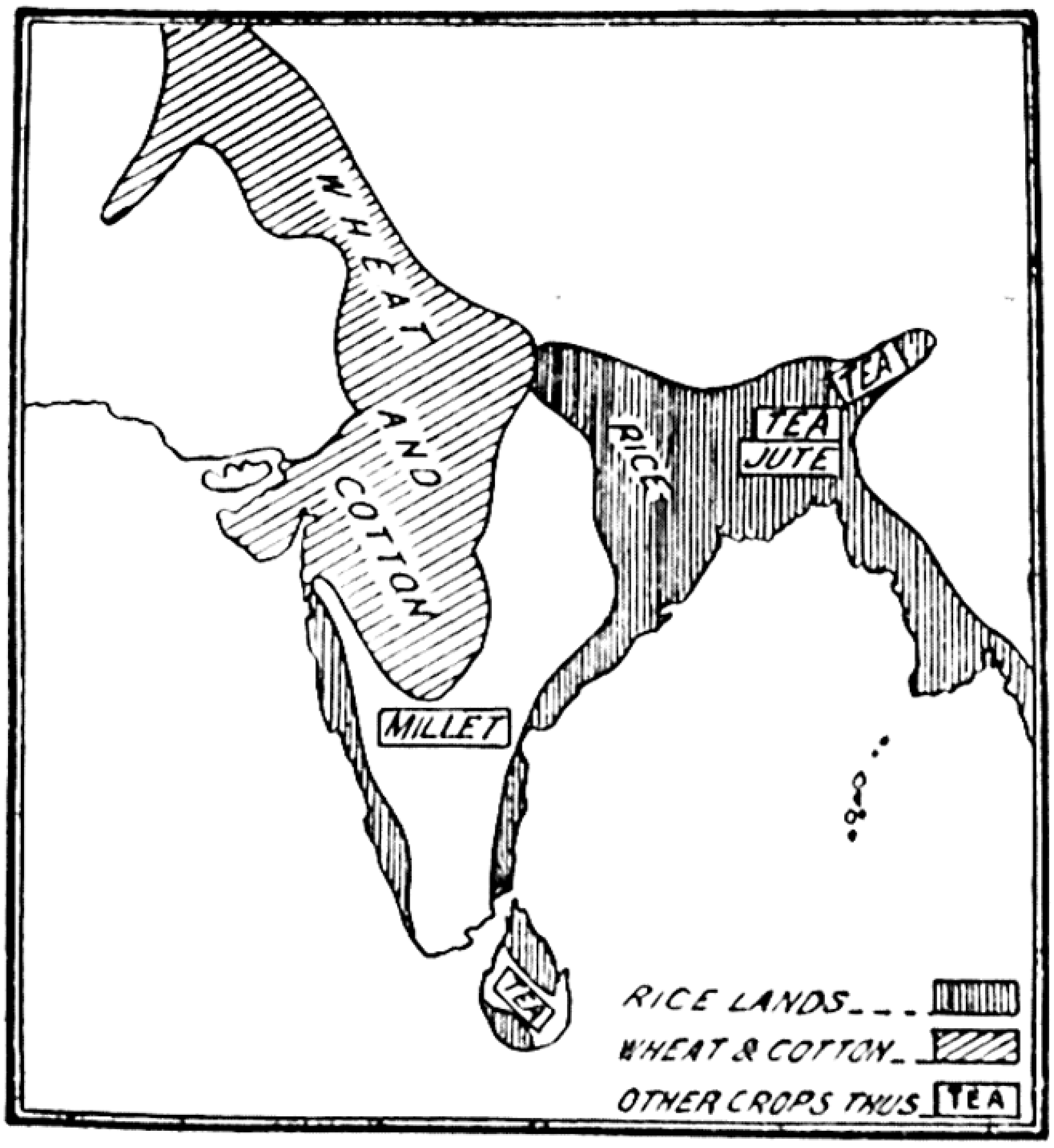


Fig. 14.

(2) *Shading or Colour Layer Method.* Distribution is shown by various methods of black and white shading or by different tints of colours. This method is useful for average figures per unit area.

The chief defect of this method is that the distribution is shown uniform over the whole area, and no account is taken of waste-land.

If colours are used instead of black and white shading it is better to use one colour for each commondity using various tints or shades for various densities.

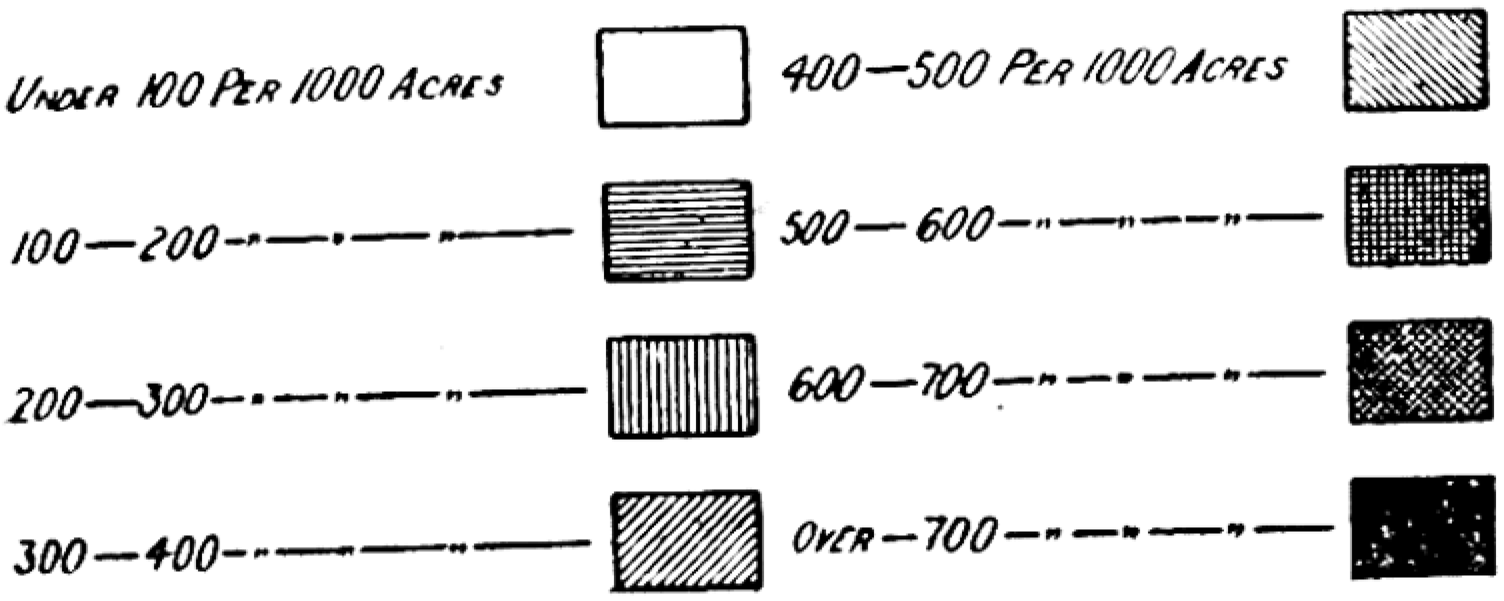


Fig. 15.

Fig. 15 shows the key to black and white shading.

(3) *The Dot method.* This method is useful for absolute figures, *i.e.*, when exact or absolute figures are available. A unit number, say 1,000 to 5,000 according to density and scale of the map, is represented by one dot over the place it is cultivated. The advantage of this method is that the waste land may be avoided. The unit must be selected with care. The dots must not be too numerous ; nor must they be too small. [See Fig. 16.]

Apart from stocks and crops, the dot method may be used in many other cases, *e.g.* :—

(*i*) In a coal-field map, for the sites of coal-mines. The size of the dot can be varied according to the number of men engaged in each mine.

(*ii*) Sites of fairs, markets, factories, etc.

**32. Population Maps.** Population maps may be of two types :—

(1) Showing the number of persons per unit area ; shading or colour layer method is most suitable for these maps.

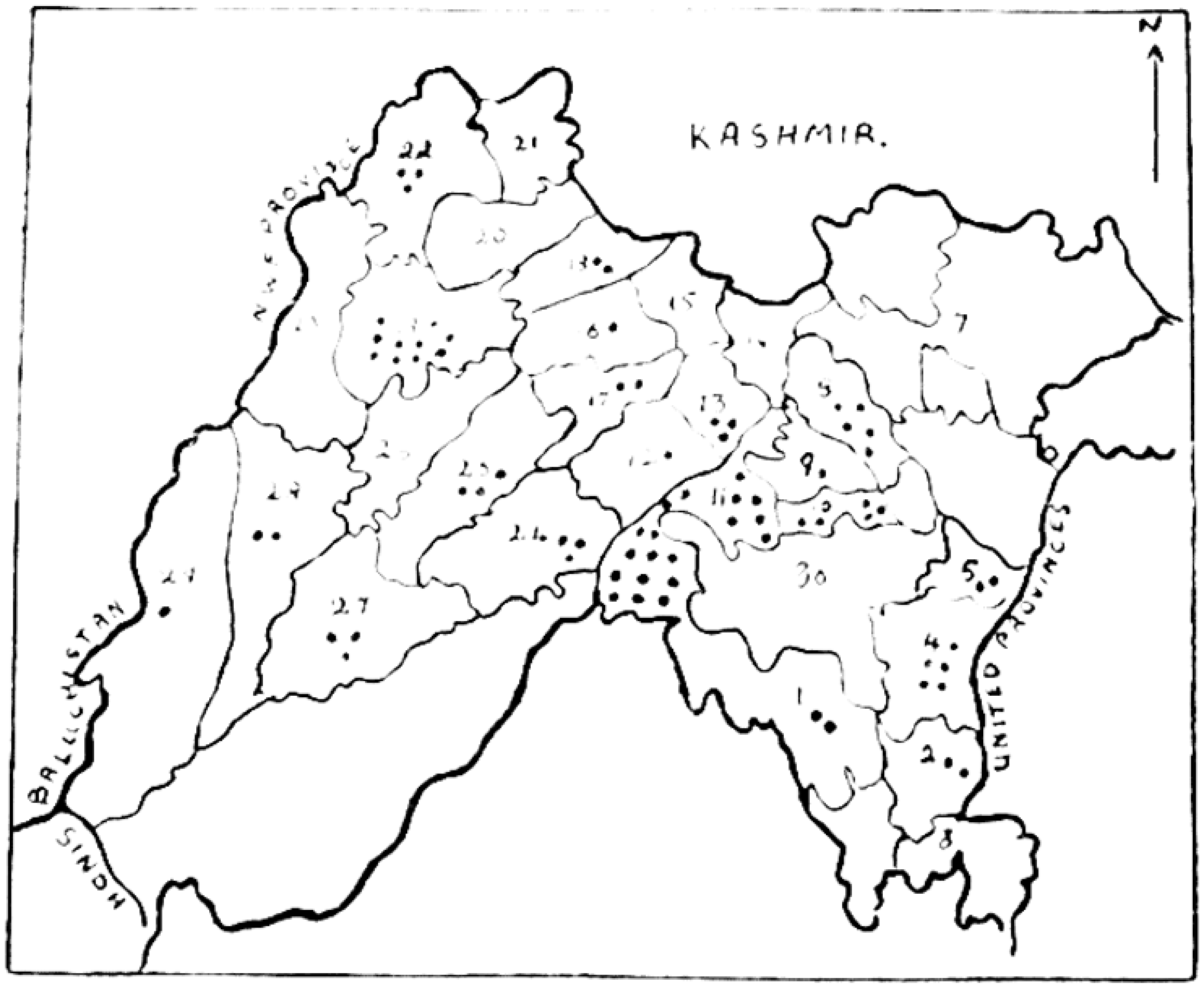
(2) Showing actual population ; the dot method, using a convenient unit, is generally used for these maps.

Sometimes the shading and dot methods are combined, so that the same map would give the average and the actual figures.

NOTE.—Distributional maps have certain limitations. Numbers vary greatly from season to season, and year to year. A map made on one year's figures will not give us a true picture. Moreover the year selected may be an abnormal year. These maps are usually based upon statistics for an average term of years, usually five years.

Population maps are based on census returns which are made once in ten years.

### MAP OF THE PUNJAB, SHOWING THE YIELD OF GRAM. YEAR 1938—1939



Scale : ● (one dot = 50,000 tons)
Fig. 16.

### MAP OF THE PUNJAB SHOWING DENSITY OF POPULATION IN THE YEAR 1931

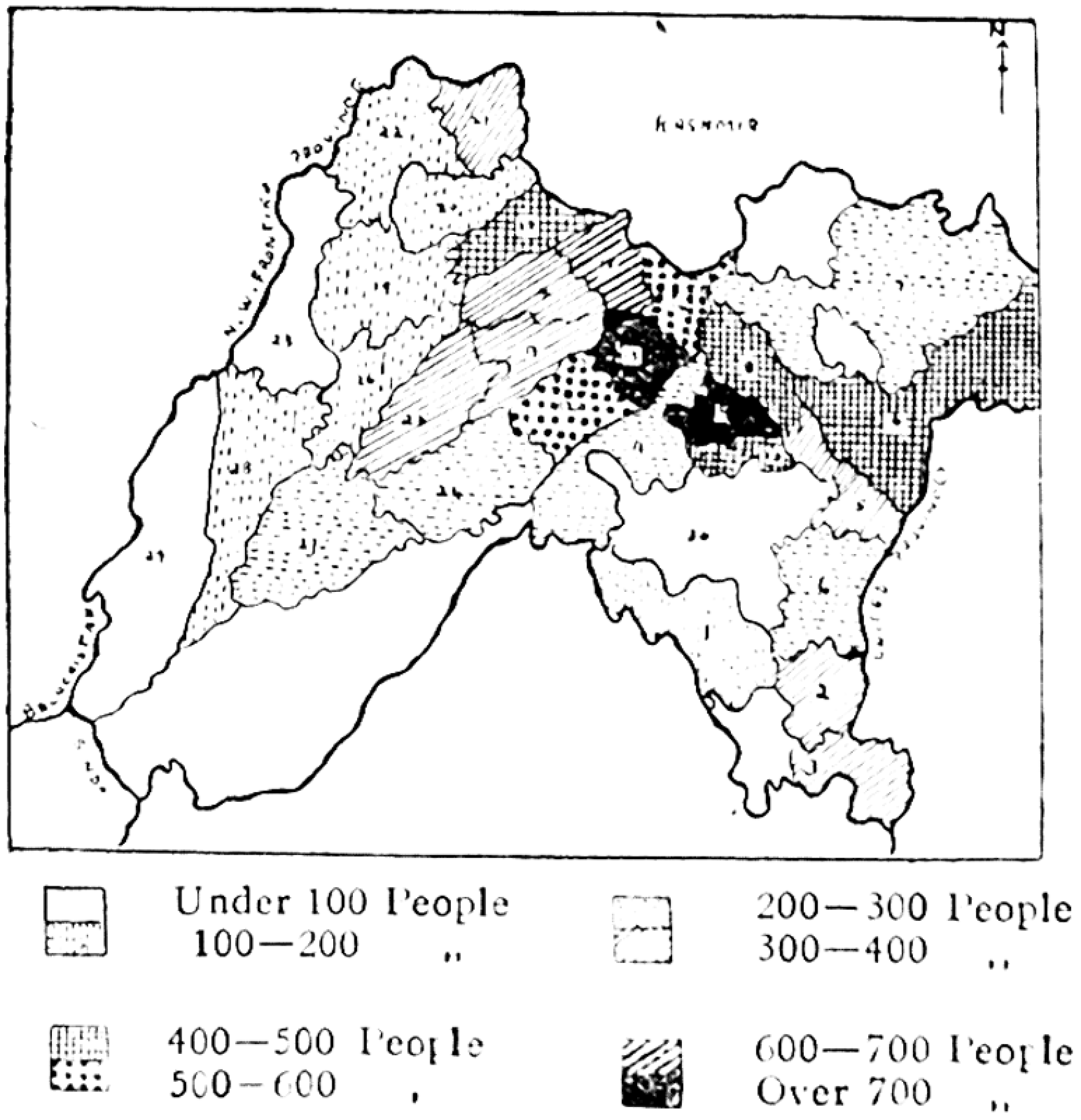


Fig. 17.

Table showing the number of people per square mile.

| | | |
|---|---|---|
| 1. | Hissar ... | 174 |
| 2. | Rohtak ... | 354 |
| 3. | Gurgaon ... | 384 |
| 4. | Karnal ... | 271 |
| 5. | Ambala ... | 397 |
| 6. | Simla ... | 454 |
| 7. | Kangra ... | 206 |
| 8. | Hoshiarpur ... | 457 |
| 9. | Jullundur ... | 703 |
| 10. | Ludhiana ... | 482 |
| 11. | Ferozepur ... | 284 |
| 12. | Lahore ... | 531 |
| 13. | Amritsar ... | 710 |
| 14. | Gurdaspur ... | 510 |
| 15. | Sialkot ... | 624 |
| 16. | Gujranwala ... | 320 |
| 17. | Sheikhupura ... | 301 |
| 18. | Gujrat ... | 405 |
| 19. | Shahpur ... | 171 |
| 20. | Jhelum ... | 133 |
| 21. | Rawalpindi ... | 309 |
| 22. | Attock ... | 140 |
| 23. | Mianwali ... | 76 |
| 24. | Montgomery ... | 224 |
| 25. | Lyallpur ... | 354 |
| 26. | Jhang ... | 146 |
| 27. | Multan ... | 220 |
| 28. | Muzaftargarh ... | 200 |
| 29. | D. G. Khan ... | 106 |
| 30. | Punjab States ... | 96 |

**33. Statistical Diagrams.** Statistical diagrams show at a glance the meaning and importance of the facts and figures without reference to the exact figures.

**34. Isopleths** are lines on a map which connect places of equal density or value of distribution of any element ; *e.g*.,

*Isotherms*, connecting places of equal temberature ;
*Isohyets*, connecting places of equal rainfall ;
*Isobars*, connecting places of equal pressure.
Contours, which connect places of equal height, may be regarded as Isopleths.

The following methods are usually used :—

(1) **Line Graphs.** By a graph showing the variation from year to year. In general, it shows the change of one variable with reference to another. One of the variables is usually time (days, months, years, etc.) When a line graph shows a continuous variation, *e.g*., pressure, temperature, the points must be connected with a continuous smooth curve. If it shows a non-continuous variation, *e.g*., the price curve of a commodity or rainfall; the points should be joined with a jagged line.

The vertical scale should be so selected that the curve should not show too sharp a vertical variation.

(2) **Bar Graphs** are used for simple comparison of quantities. The quantities are shown by bars of equal width, the length being proportional to the quantity on a suitable scale. The bars could be vertical or horizontal : in horizontal bars, the labels are more easily read.

Bar graphs are not satisfactory when one quantity is several times larger than the other.

Sometimes bars are shown on both sides of a vertical zero line ; such diagrams are known as *Mirrored bar graphs*.

(3) **Rectangular Diagrams.** In these diagrams a large area, *e.g*., a continent or country is sub-divided into small regions, each of which is represented by a rectangle. The rectangle is proportional in area to the value it represents. It is better to begin with the larger division and arrive at the smaller ones by proportionate halving. Calculations can be made easily if it is drawn on graph paper, so that one small square of the graph paper corresponds to a round number of units.

If one of the variables is time, the production or price of any commodity can also be shown by rectangular diagrams as shown in the figure.

(4) **Pie Graphs or Wheel Diagrams.** The distribution is shown by circles of different sizes, the area of each circle being proportionate to the quantity or amount to be shown. The radii of circles are proportionate to the square roots of the quantities.

The circles may cut into each other if this does not make the map confusing. The circle may also be subdivided and the subdivisions marked with various tints.

Pie graphs are used when the data are not sufficient to prepare a dot map or when the distribution is strongly localized, *e.g.*, on a map showing water power or production of Petroleum.

rectangular method

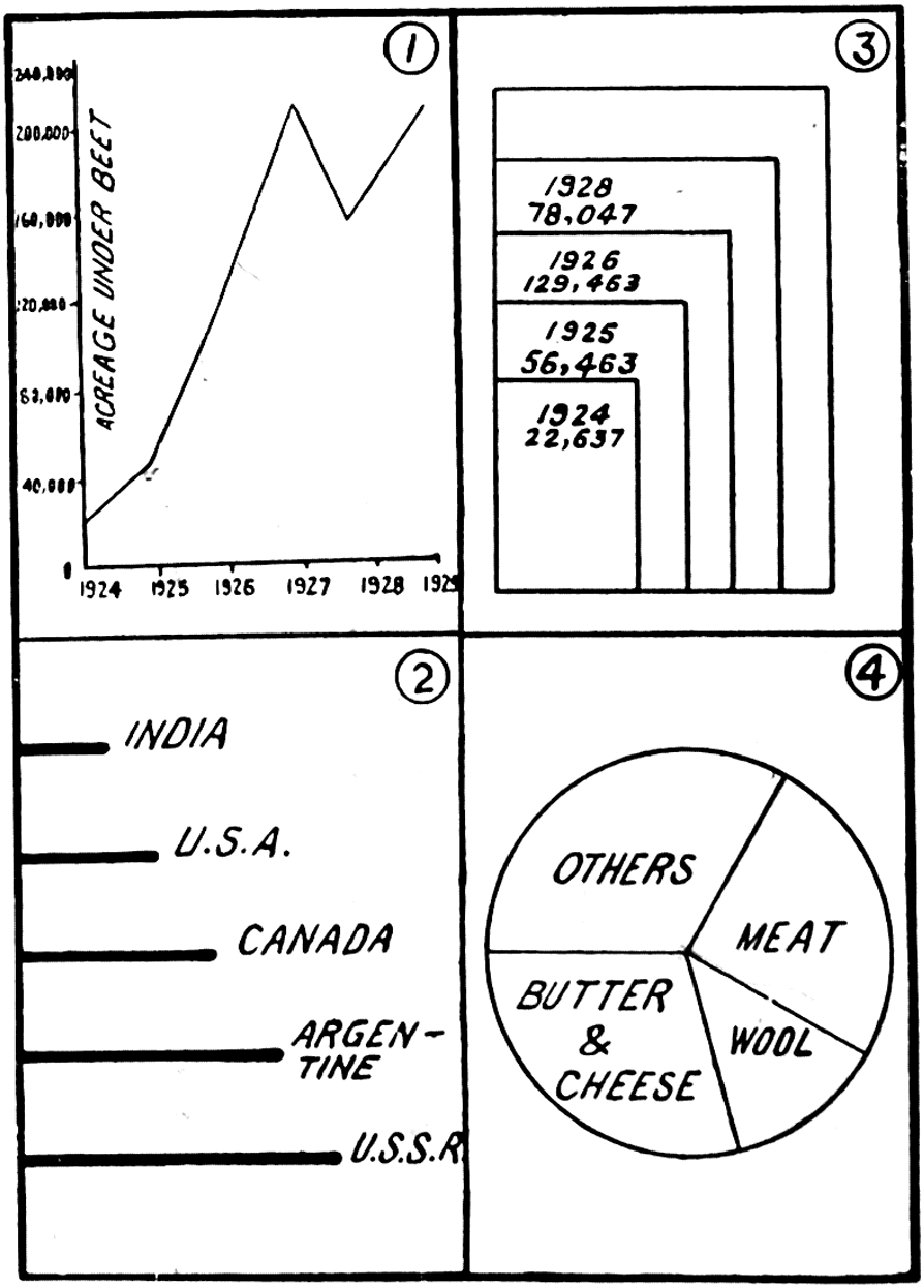


Fig. 18.

NOTE.—Data for preparing Statistical and Distributional maps may be had from the following :—

Geographical Statistics by S. J. Elliott & T. S. Goadby.
The Indian Year Book.

The Statesman's Year Book.
Agricultural Statistics of the Punjab (The Board of Economic Inquiry).
The Crop and Season Report of the Punjab.

## EXERCISES

1. (*a*) Describe carefully the data you would require for the construction of agricultural maps of the Punjab.

(*b*) Discuss and illustrate the methods you would adopt to construct a map of the Punjab, showing the distribution of wheat cultivation. *(Punjab Univ., Inter., 1934)*

2. What are the various methods adopted to represent diagrammatically the statistics of production ? Illustrate. *(Punjab Univ., Inter., 1935)*

3. Supposing that you are to present by means of maps and diagrams, an analysis of the statistics of production of Lahore District ; explain briefly how you would collect and use your data, giving specimen maps and diagrams. *(Punjab Univ., Inter., 1936)*

4. You are required to prepare an analysis of the statistics of production of India. Explain how you would collect and use your data, giving specimen maps and diagrams. *(Punjab Univ., Inter., 1937)*

5. You are required to prepare an agricultural survey of Lahore. Explain how you would collect and use your data giving specimen maps and diagrams. *(Punjab Univ., Inter., Suppl. 1937)*

6. What do you understand by the 'Dot System' employed in the preparation of distribution maps ? What is the advantage ? Where does this system fail ? Give examples. *(Punjab Univ., Inter., April, 1938)*

✓ 7. Represent graphically (by circles) the population of the following towns :—

| Town | Persons | Males | Females | Town | Persons | Males | Females |
|---|---|---|---|---|---|---|---|
| Lahore | 400075 | 253846 | 146229 | Rawalpindi | 75767 | 46086 | 29681 |
| Amritsar | 263210 | 157823 | 105387 | Multan | 108351 | 60800 | 47551 |

*(Punjab Univ., Inter., April, 1941)*

8. Draw a map of India and on it show the trade of the following ports according to the data given :

**1934-35 (crores of rupees)**

| Ports | Total value of Trade | Value of Imports | Value of Exports |
|---|---|---|---|
| Calcutta ... | 90·62 | 35·32 | 55·30 |
| Bombay ... | 86·54 | 53·66 | 32·88 |
| Karachi ... | 31·66 | 15·24 | 16·42 |
| Madras ... | 20·74 | 12·04 | 8·70 |

*(Punjab Univ., Inter., Sept. 1941)*

Takes the square root
give quantity
to be shown
Then choose
a suitable scale.

out of course.

# CHAPTER VI

## FIELD WORK

**35.** The term *surveying* includes the methods of making measurements in the field from which maps are prepared ; in other words it is the science of ascertaining the boundaries and superficial extent of any portion of the earth's surface.

Suppose you are asked to draw a map of a playing field. You will first view the field as a whole, draw a skeleton of the whole field and then measure its sides and included angles. The most important principle in all surveying is to work from the whole to the part.

**36. Measuring of Distance by the Amateur.** The most important operation in surveying is the measuring of distance over the ground. An amateur will find the following methods quite suitable :—

(1) *Pacing.*—Our natural walking pace upon level ground, provided we are not carrying a weight is ordinarily uniform. A little practice to pace unconsciously will illustrate this. The value of the pace can be estimated by pacing a measured distance say 300 yards, two or three times.

(2) *Revolutions of a wheel.*—Tie a piece of white tape to the front wheel of the bicycle. Count the revolutions of the wheel in running over a distance. This method is only suitable for long distances and provided you cycle straight. The circumference of the wheel may be measured by (1) trial of one revolution on the ground, and (2) from the formula : circumference $= 2\pi r$ where $r =$ radius of the wheel.

(3) *Time and Rate.*—For long distances, *e.g.*, route marching, touring, exploration, etc., the distance from one point to another may be ascertained from the time taken.

**37. Surveying by Chain.** When the area to be surveyed is small, *e.g.*, a playground, this can be done by a "chain," a measuring tape and a few arrows.

*Gunter's Chain.* This chain is 22 yards long (the length of a cricket pitch) and is divided into 100 links. The two end links are provided with handles and each tenth link is marked by a brass tab.

This unit of length is convenient for land surveying because 10 chains make one furlong and because

$$\begin{aligned} 1 \text{ square chain} &= 484 \text{ square yards} \\ &= \frac{1}{10} \text{ acre.} \end{aligned}$$

Gunter's chain is sometimes known as the *Short chain.* A chain of 100 ft. length is known as the *Long chain.* The short chain is used for the purpose of finding areas ; the long chain is preferable for measuring distances when no areas are required.

Every chain is provided with ten arrows, made of iron or steel and pointed at the bottom.

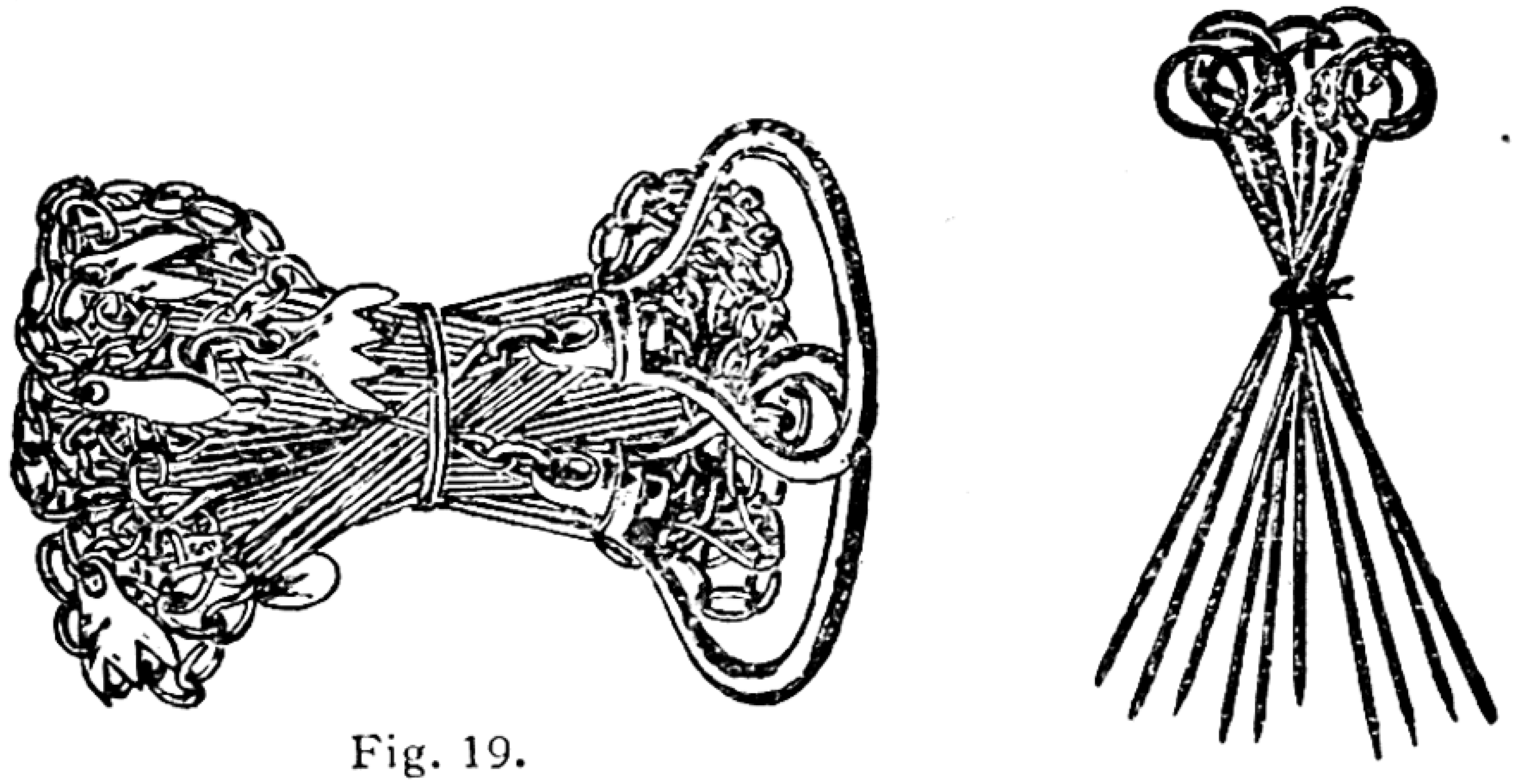


Fig. 19.

*The Tape.* The measuring tape is marked in feet and inches ; hence if used in conjunction with the chain, the readings must be converted to yards, or *vice versa.*

*The Field Book.* This is a note-book for placing the records. It has two parallel lines, about $\frac{1}{2}$ inch apart down the centre. These two lines form the main chain column to the line traversed or walked along by the surveyor.

**38. Method of Surveying.** Suppose we wish to survey an irregular field ABCD (see Fig. 20). Draw in a rough note-book an outline of the plan and letter the corners. Now measure diagonally across the field from one corner to another. In order to do this fix two ranging poles, one at the beginning and the other at the end of the line (*i.e.*, at A and D). The two ends of the chain are held by the 'leader' and the 'follower.' The follower stands at A, and the leader walks in the direction of D carrying the arrows. As soon as the chain is taut, the leader faces the follower, who then gives him hand-signs which way to go, sighting him with the extreme pole at D.

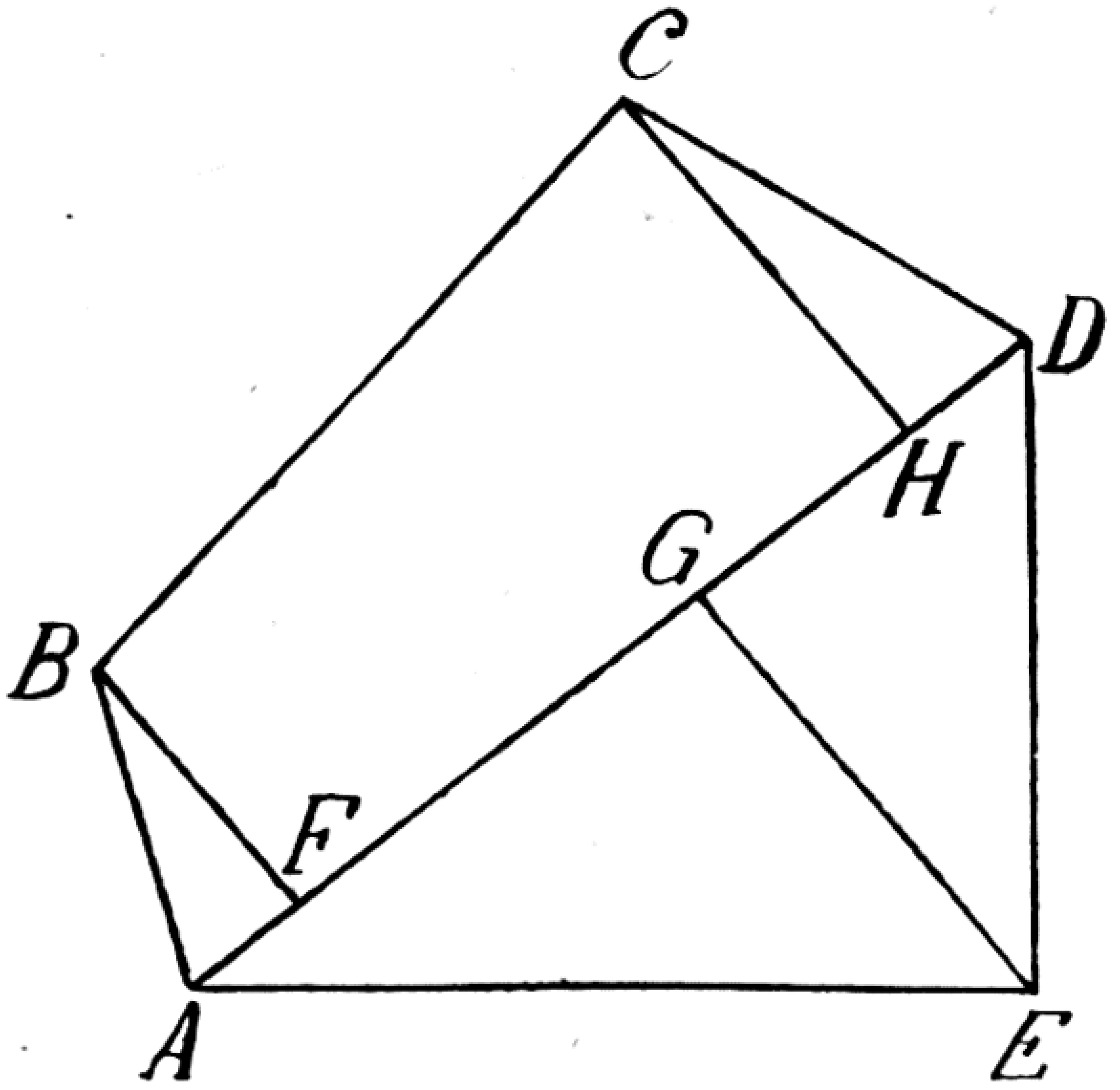


Fig. 20.

When the chain is fully extended, the leader fixes the first arrow in the ground, and advances pulling the chain. He is followed by the follower, and the same routine is followed until the whole distance is stepped. The follower then counts the arrows and the overlap (if any) of the chain at the last ranging pole.

**39. Offsets.** At intervals, perpendicular distances are measured to the fences or corners or other boundaries which are to be fixed. These secondary measurements are known as **offsets.** These may be measured by a tape, which is laid on the ground and stretched tight. The direction of the tape is altered till it is perpendicular to the chain. In more accurate working the **cross staff** is used to secure readings to objects being taken at right angles to the main chain line. A cheap design may be made by taking a tripod stand with a revolving wooden top. Rule two lines on the top cutting each other at right angles ; insert vertically upright pins at the two extremities of each line. Move the wooden top over the chain until two of the pins are aligned to A and D, and the remaining two simultaneously on to B. This gives the position of F. The positions G and H are similarly obtained, and the offsets measured.

The results are recorded in the field-book as follows :—

| | | | | |
|---|---|---|---|---|
| | | To D | | |
| | | 855 | | |
| To C | 330 | 690 | | |
| | | 540 | 420 | to E |
| To B | 275 | 90 | | |
| | | From A | | |

The distances are entered in links ; the central column is kept for measurements from the starting point and the side column for the lengths of offsets on each side of the line.

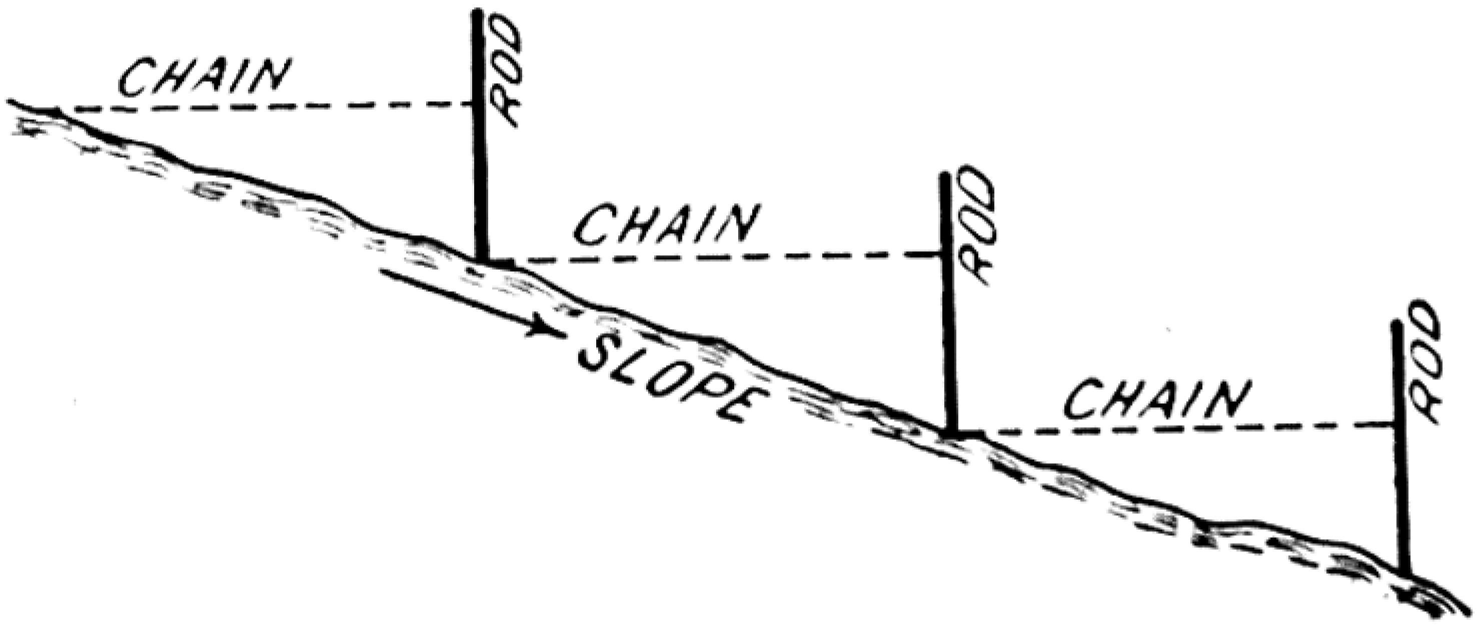


Fig. 21.

**Sloping Ground.** In the case of sloping ground the *horizontal* distance is required. This can be found by chaining in steps. The leader holds one end of the chain against a vertical rod at such a height that when stretched tight with the other end on the ground, it appears to be horizontal.

**40. Showing North Point.** The direction of North and South points must be shown on the map. Set up the compass and lay out on the ground and draw a line which runs due north and south by compass; survey this line as part of the survey.

**41. Plan of a field where a building obstructs the drawing of the diagonal.** In this case three tie lines, just clearing the corners of the building, can be drawn and measured as before. The angle will be automatically fixed as shown in Fig. 22.

**42. Plane-Tabling.** The **Plane-table** in its simplest form consists of a drawing board with a screw attachment underneath for fitting the table to the top of a tripod. The plane-table is the most valuable means of supplying the detail for a topographical survey of a country.

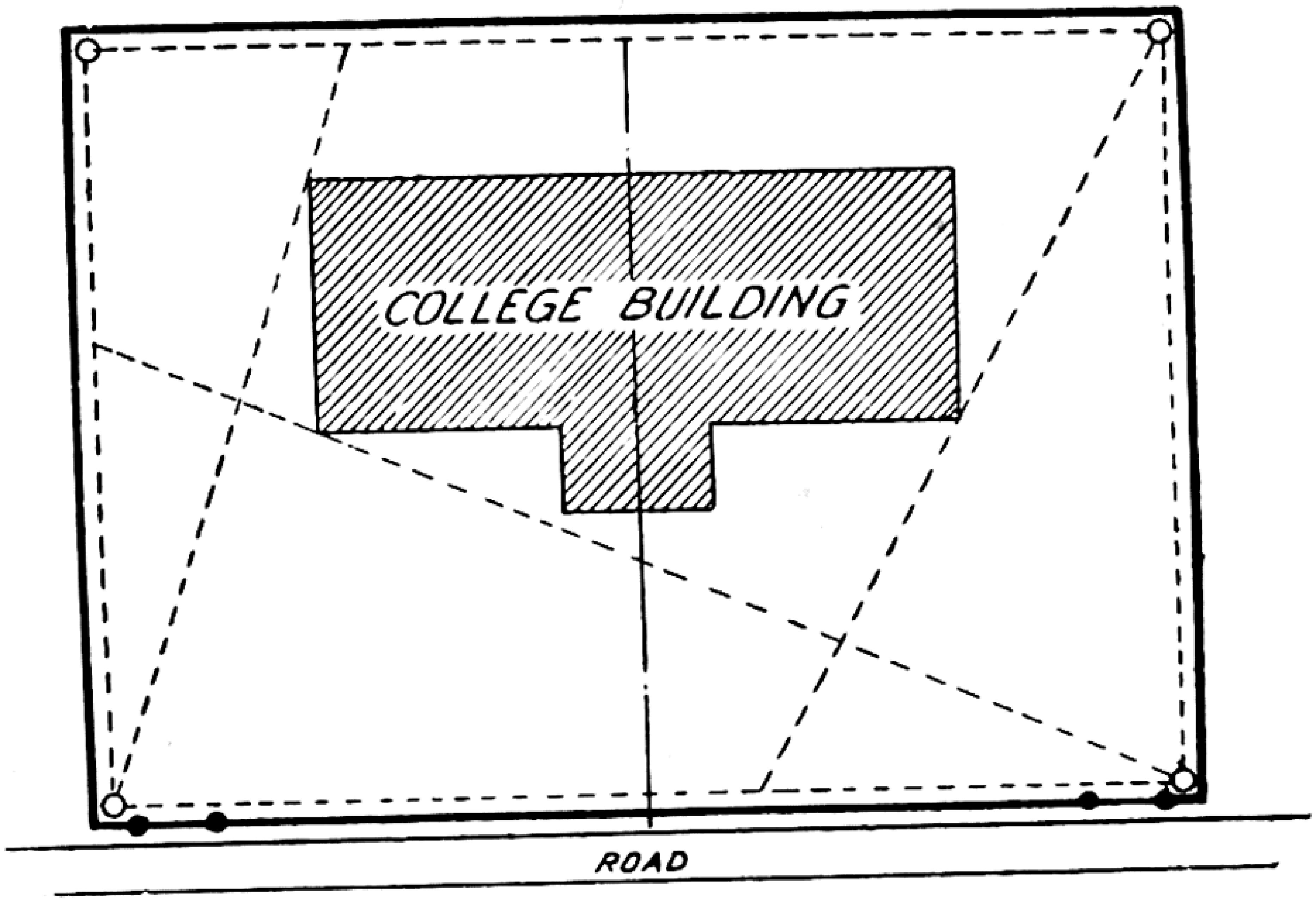


Fig. 22.

The tripod stands about 4 feet high ; the legs should be strong and rigid. The top board is usually 15″ square or 18″ × 24″. No iron or steel is used in the fittings of the tripod or the top.

*Alidade.* The Alidade or the Sighting Rule consists of a heavy straight-edge, at either end of which is mounted a hinged sight. The back-sight has a narrow vertical slit in it ; the fore a wider slit, in which is strung a vertical wire. The line of sight is parallel to the side of the straight-edge. The alidade is not attached to the board but simply rests on it.

*Box-compass.* The Box-compass consists of a magnetic needle about 5″ long fitted into a metal trough, and the whole is closed in a case of wood having truly parallel sides.

*Method of using the plane-table.* Mount a sheet of drawing paper several inches larger than the table on the top ; this can be done by damping the paper and drying it on the board in a stretched condition. It is fixed by pasting the overlap on the underside of the board. Very small flat-headed drawing pins of brass may be used if necessary.

The plane-tabler must also provide himself with field glasses, scales, rubber, penknife, and two pencils—one a 2H for drawing lines, the other H for drawing in the details.

Choose two stations A and B. Measure the distance AB ; this line will serve as the base line. Scale it on the drawing before fixing it in such a position that the map will fit in well.

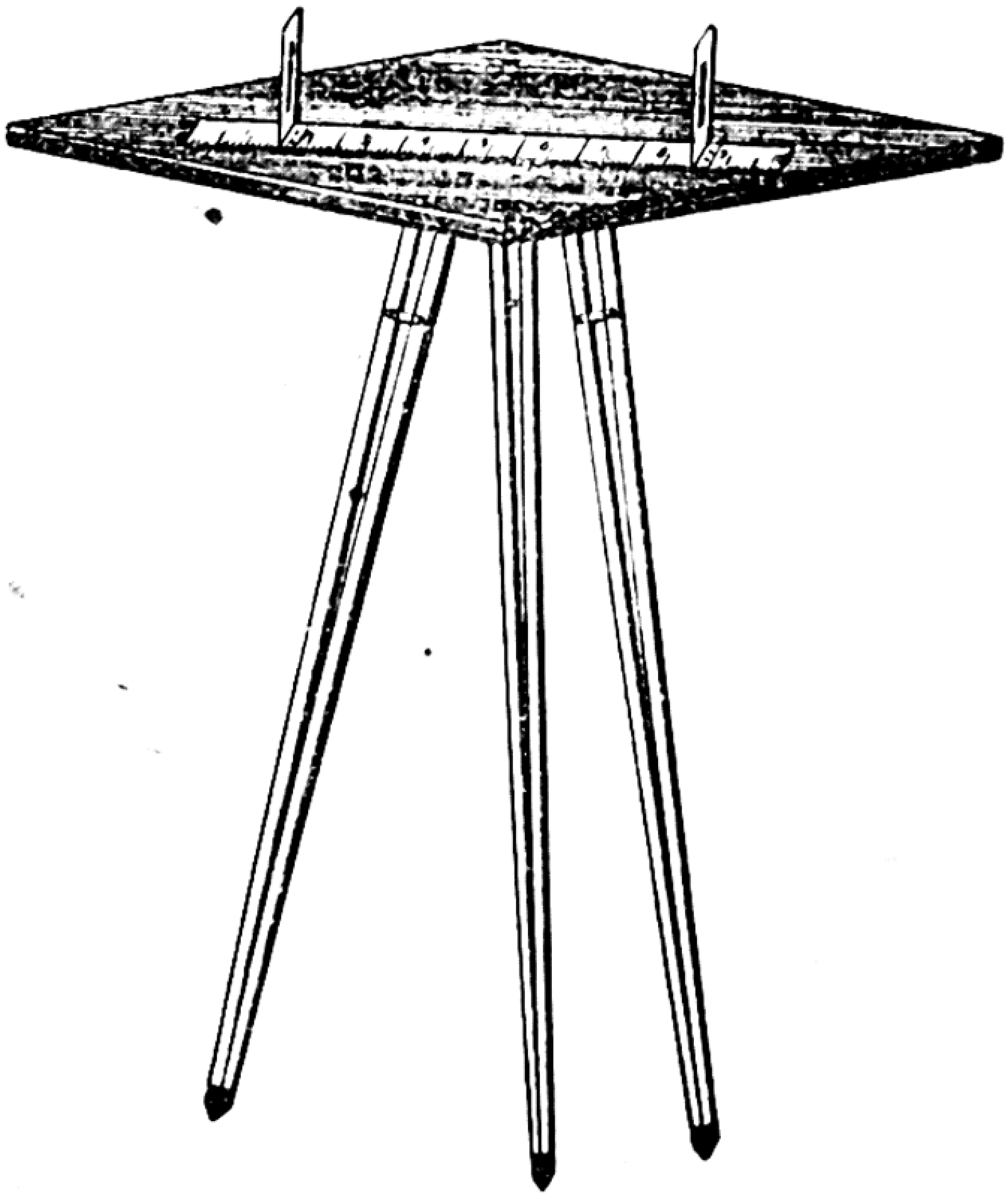


Fig. 23.

Set the table at A exactly over the station on the ground. Place the alidade along the line drawn to represent the base-line. Swing the table round until the distant end of the base comes upon the sight. The table is then *oriented, i.e.,* it lies in the correct direction. Clamp the board in this position and check the sight after clamping. Lift the alidade off the board and turn its sights upon a few conspicuous points. As each point is sighted draw the ray to it on the paper using the ruling edge of the alidade, and label the ray. A pencilled description of each ray is preferable to numbering or lettering the rays. *Do not turn the board.* The rays should be drawn long enough to pass through the estimated position of the points sighted.

Repeat the whole of the work from the station B. We thus see that several points will be fixed on the table by the intersection of rays drawn from both ends of the base line : these poines are called *intersected points*. The survey can be checked by occupying one of these intersected points and sighting at A and B. A position must be fixed by the intersection of two rays and must be exactly confirmed by a third ray.

Before vacating any point, sketch in the detail around it. This is done by eye, aided by short rays down to all important points, the distance to these features being measured by a tape.

**43. Triangulation.** Surveying depends upon building up of triangles, and the accurate method employed to fix these points forming the framework of the survey of the country is called **Triangulation.** The details between these points (known as trigonometrical stations or briefly trig. points) may be mapped by chain survey.

A triangle has three sides and three angles ; we know from geometry, that a triangle can be completely determined when the following are known—

(1) If the lengths of two sides and the angle between them are known ; this forms the basis of traversing.

(2) If the lengths of three sides are known ; this is taken advantage of in chain survey.

(3) If the length of one side, and two angles are known ; this is the basis of triangulation.

In triangulation the three angles are always measured, as their sum is a check on the accuracy of the measurements.

The great advantage of triangulation is that only one distance is measured, called the *base line*, and it can be done on the most suitable part of the area to be surveyed. If more than one base can be measured at considerable distances from each other, the measured length can be compared with the calculated length to serve as a check on the accuracy of the work. The shape of the triangles and the size of the angles have an important bearing on triangulation. A most useful rule is to have the triangles as *nearly* equilateral as possible.

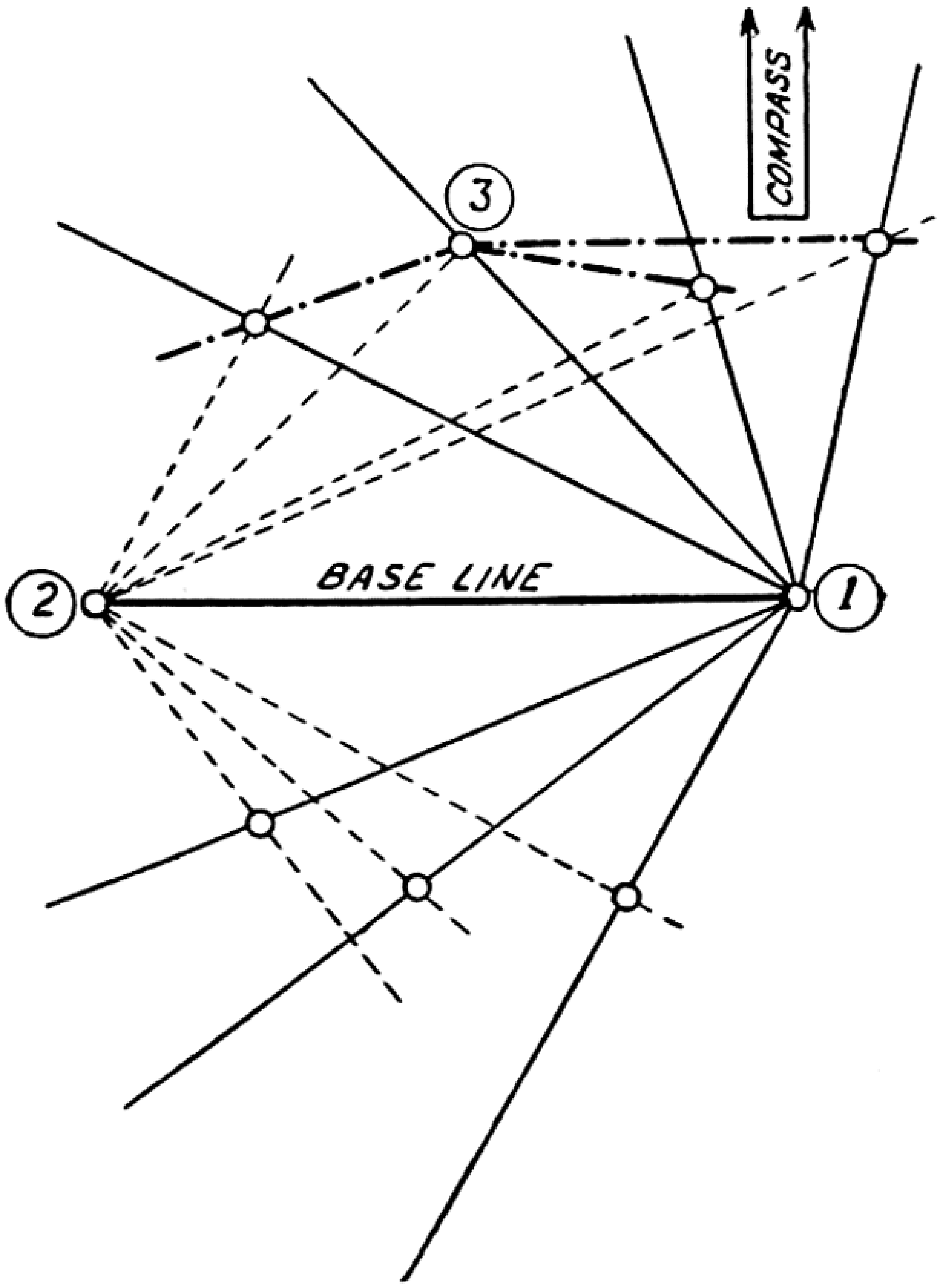


Fig. 24.

**44. True North.** The true North may be found by the following methods :

(1) *By means of the Pole Star.* For Northern Hemisphere : A constellation of seven stars known as 'the Great Bear' or 'Ursa Major' can be recognized by its shape like a soup-ladle. The two stars forming the side of the cup, known as the *pointers*, always point to the bright Pole Star.

In the Southern Hemisphere the Southern Cross is used to find the direction. It is true South when its longest limb is vertical.

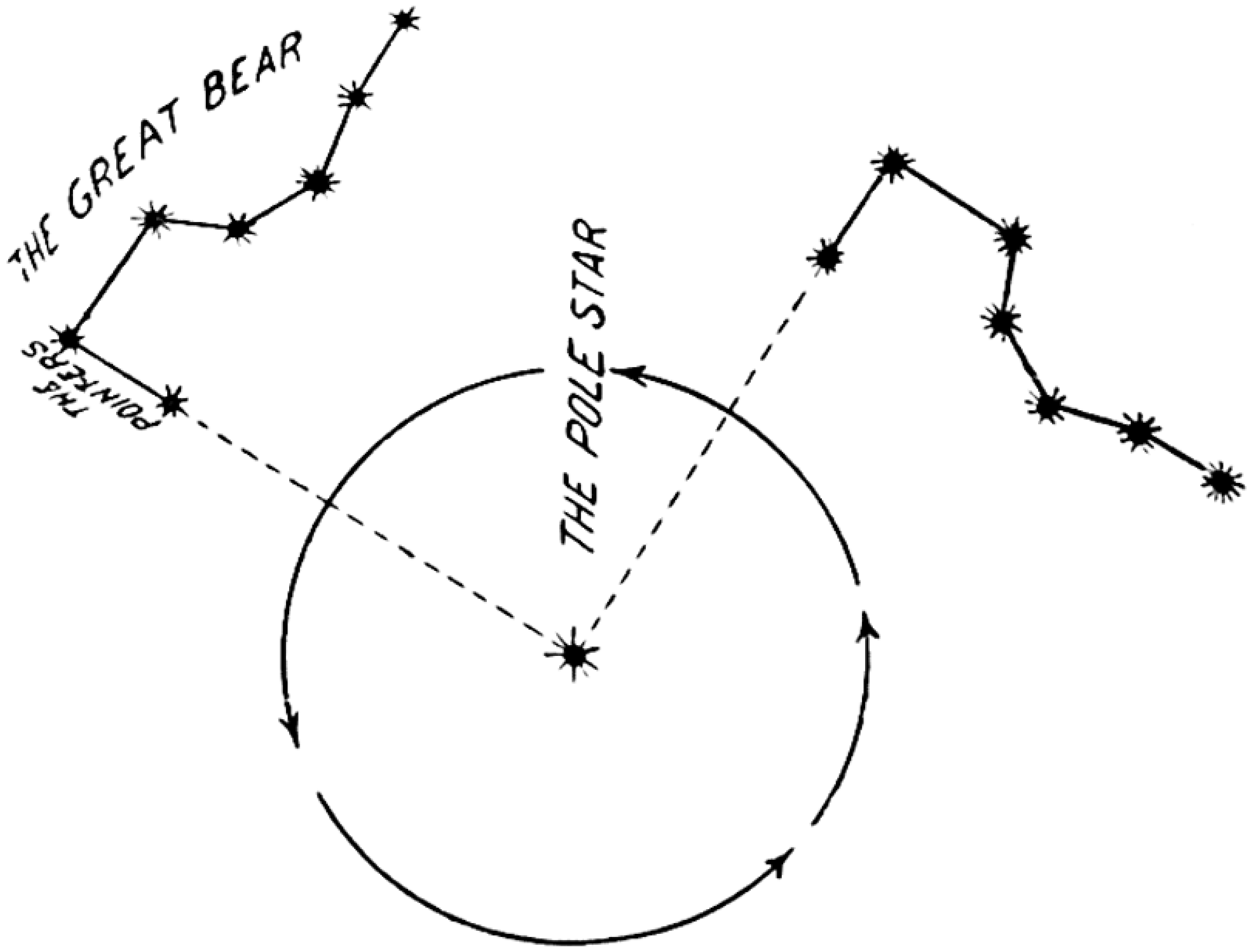


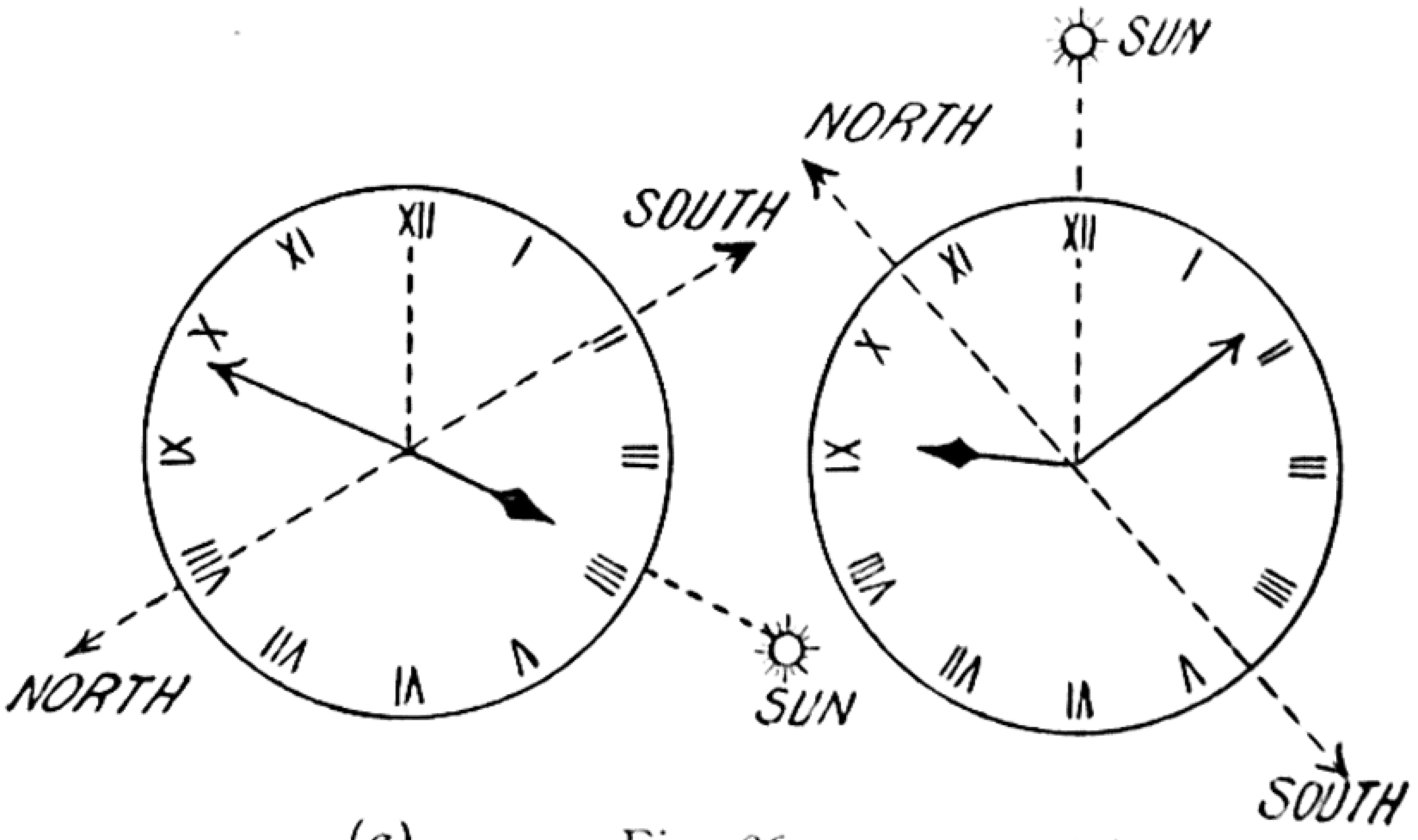
Fig. 25.

(2) *By means of the Sun.* Set up a stick vertically in the ground. At 12 noon its shadow will point away from the stick approximately due North.

(3) *By a Watch.* This is a rough method and is based on the assumption that at noon by a watch showing local time the sun is on the meridian.

(*i*) *For Northern Hemisphere.* Hold the watch in a horizontal position and turn it until the hour hand points to the sun. Draw a line from the centre of the watch to 12 o'clock. The line bisecting the angle made by the hour hand and 12 o'clock points to South.

(*ii*) *For Southern Hemisphere.* Join the centre to 12 o'clock. Point this line at the sun. Bisect the angle formed by this line and the hour hand; the bisector points to North.



(*a*) Fig. 26. (*b*)

45. **Magnetic North.** Take a magnetic compass. Pin a sheet of paper on a level table and stand a magnetic needle upon it. When the needle is steady, draw a line on the paper parallel to the direction of the needle. This line will indicate the magnetic North and South direction.

The compass will give a North line but it will not be true (Geographic) North. The compass needle does not point to the true North Pole. Hence we have, so to speak, two North Poles, *viz.*, 1, the Geographical (or True) North, and 2, the Magnetic North. The Magnetic Noth Pole is not a fixed point but is slowly moving its position from year to year. The angle between the Magnetic North and the Geographic North is called *Magnetic declination* or *variation of the compass*.

If the magnetic variation for a particular place at a particular time is known, the true north can be easily found.

Suppose the magnetic variation is 12°W. This means that the magnetic meridian is 12°W of the true Geographical meridian. Draw a line cutting the magnetic meridian at an angle of 12° to the East. This line will be the Geographical meridian.

**46. Bearings.** A *true bearing* is the angle which a line makes with the true North and South line measured from it, in a *clockwise* direction. A *magnetic bearing* is the angle which a line makes with the magnetic North and South line measured from it in a *clockwise* direction. To convert true bearings into magnetic bearings *add* the magnetic variation; to convert magnetic bearings into true bearings *subtract* the magnetic variation when the variation is West. When the variation is East, interchange the words *add* and *subtract*.

The following formula is useful in remembering the above :

True bearing ± Magnetic Variation = Magnetic Bearing.

The + sign to be used when the variation is West and the − sign to be used when the variation is East.

**47. Triangulation Survey.** In the Survey of India, the triangles formed great chains North and South, and East and West. The following is an outline description of the method of survey :—

(1) Study the country and select suitable points for the apices of the triangles. Make a rough diagram to show their respective positions. Beacons are erected or signals are posted at points to which and from which observations can be made.

(2) Measure the base line, which should be at least one mile long. The base line should be measured with steel tapes either along the carefully levelled ground or suspended from trestles. Corrections for temperature, alignment, height above sea level, etc. should be made. The base line should be measured very accurately, as upon the base depends the accuracy of the whole of the subsequent work.

(3) The base is now extended by well-conditioned triangles, and the triangulation of the whole area undertaken. The thecdolite* is centred at one end of the base and the angles to the first points to the base extension are

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* The Theoelolite is an instrument for measuring angles both in the horizontal and vertical plane,

measured. The instrument is then centred over the other end of the base, and angles to the same points observed.

(4) Further points are then determined and the angles measured as before, and the process continued till the whole triangulation is complete.

(5) Another base is then measured. Calculate its length as computed from the triangulation and compare the two as a check on the accuracy of the work.

## EXERCISES

1. The following is a page from a field-book. Draw a plan of the field, choosing any suitable scale :—

| | | | | |
|---|---|---|---|---|
| | | To D | | |
| | | 600 | | |
| | | 500 | 160 | to C |
| to E | 130 | 420 | | |
| to F | 180 | 220 | | |
| | | 150 | 200 | to B |
| | | 0 | | |
| | | From A | | |

Measurements in Links

2. A tree in the above field is 280 links from B and 110 links from C. Mark its position on the plan, and calculate its distance from A.

3. How would you find the width of a river without crossing it? [Use the principle of similar triangles.]

4. Explain when you would use a plane-table for map making and when you would use the surveyor's chain. Give reasons.

5. How would you carry out a graphic triangulation with a plane-table? Describe with illustrative sketches the triangulation of an island.

6. You are given a map of Lahore District, which has been covered by triangulation in a careful trigonometrical survey. How would you fill in topographical details?

7. Convert the following magnetic bearings into true bearings (*a*) when the variation is 10°E. and (*b*) when the variation is 10°W :—

12° ; 50° ; 155° ; 345°

8. Convert the following true bearings into magnetic bearings (*a*) when the variation is 8° E, and (*b*) when the variation is 8° W :—

20° ; 45° ; 220° ; 348°.

9. The range from a church to a bridge is found to be 1,200 yards. The bearing given by a compass is 130°. From a tower 1,400 yards distant from the church the bearing to the bridge is 210°. Find the range from the tower to the bridge.

10. What is the principle on which maps of large areas of a country are made?

# CHAPTER VII

## WEATHER MAPS—I

Before considering the interpretation of weather maps, it is necessary to consider a few important principles and certain terms used in connection with weather maps.

**48. Meteorology** is that branch of science which treats of the phenomena of the atmosphere as regards weather and climate.

The term *Weather* includes a study of natural conditions such as temperature, sunshine, wind and rain, etc., at any particular place and time. *Climate* is simply average weather.

**49. The Atmosphere.** Air is a mixture of gases, chiefly oxygen and nitrogen; carbon dioxide and moisture are also present in varying amounts. The pressure of the atmosphere is measured by means of the barometer, and varies from time to time in any given place, and from place to place at the same time. As we ascend the pressure of the atmosphere decreases. For instance :—

Pressure at sea-level = 30 in. of mercury.
,, ,, 900 ft. = 29 ,, ,,
,, ,, 1,130 ft. = 28 ,, ,,
,, ,, 16,000 ft. = 15 ,, ,,

Hence we see that heights can be estimated by reading the barometer at different altitudes, and applying, what is called the *vertical barometric gradient, i.e.,* the rate at which the atmospheric pressure falls with altitude. *The barometer falls about one inch for every 900 ft. one rises above sea-level.* The barometer altitudes, however, are not reliable.

Similarly, there is also a falling *temperature gradient* in the atmosphere as we ascend. *The rate is 1° F. for 300 ft.* if the air is dry, but it varies very much from place to place. It is greatly affected by the amount of water vapour in the air up to about 10,000 ft.; above this the gradient is nearly constant up to about 7 miles. Higher up there is either no gradient or a very slight reversed gradient. This topmost layer is called the *stratosphere* or *isothermal layer.*

Meteorological observations to be of scientific value must be made on a uniform plan. Observations should be made at fixed hours. The central authority for the collection and publication of results of meteorological observations in India is the Meteorological Office at Poona. Poona is selected as the

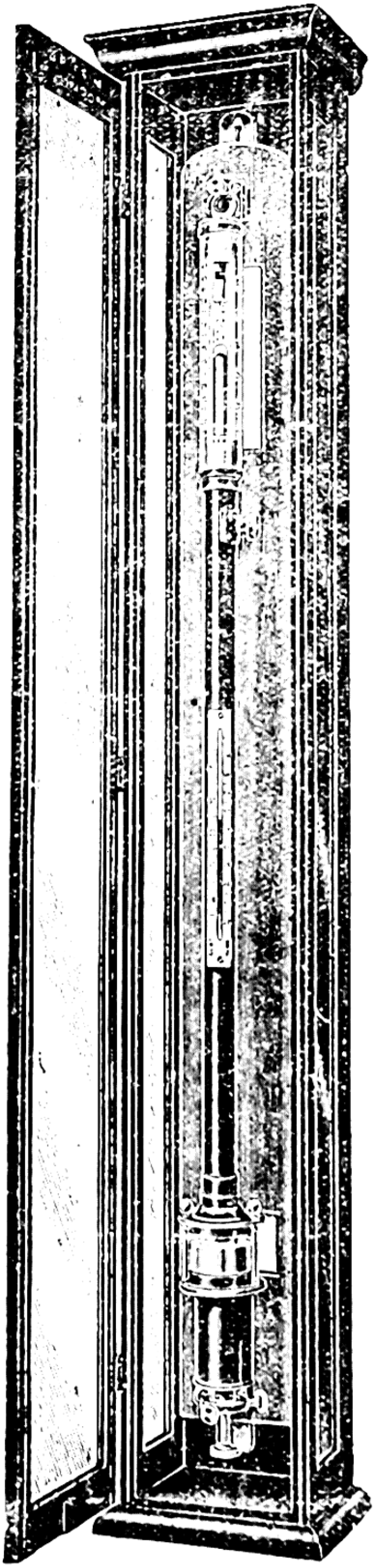

Fig. 27.

headquarters, as it is within the Monsoon range and close to more important harbours of India*.

## PRESSURE

50. **Fortin's Barometer.** This consists of a long glass tube containing mercury and inverted with its lower extremity in a reservoir of mercury. The surface of mercury in the reservoir is always kept at the same level. The lower part can be raised or lowered by means of a screw to bring the level of mercury in the reservoir just into contact with an ivory pin. The divisions on the scale indicate how high the top of the mercury column is above the point of the ivory pin. The instrument is provided with a vernier to ensure accurate reading.

51. A **Kew pattern barometer** is preferred to Fortin's barometer for general use, as there is no troublesome setting of the surface of mercury in the cistern to an ivory pointer. There is no adjusting screw at the bottom of the cistern; to allow for the rise and fall of the mercury in the cistern, the divisions of the scale are not all equal. Above the reading corresponding to 1,000 mb. the divisions on the scale are less than the true length, and below this point they are greater.

It is supported on gimbals fixed well above the centre of gravity so that it may always hang vertically.

52. **The Aneroid Barometer.** Fortin's barometer is not easily portable and is not suitable for explorers who travel from place to place. They usually employ an Aneroid barometer. It consists of a shallow metal box with thin flexible lids. The box is partially exhausted of air. An increase in the pressure of air causes the lid to be pushed inwards a little; but if the pressure of air outside the box decreases, the small amount of the air in the box will push the lid slightly outwards. A lever presses against the lid, which takes up the movements of the lid, and communicates them to an index which passes over a scale. (See Fig. 28).

53 A **Barograph** is a self-registering barometer. It consists of several aneroid barometers cemented together and provided with a mechanical device

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* The student is advised to visit a Meteorological Observatory and get a working knowledge of the instruments described in this section.

which transmits the movements, and a pointer tracing a line on a revolving drum. See Fig. 29.

**54. Graphic Record of Barometer Readings.** Study carefully the daily Weather Report of India to be obtained from the Meteorological Office, Poona.

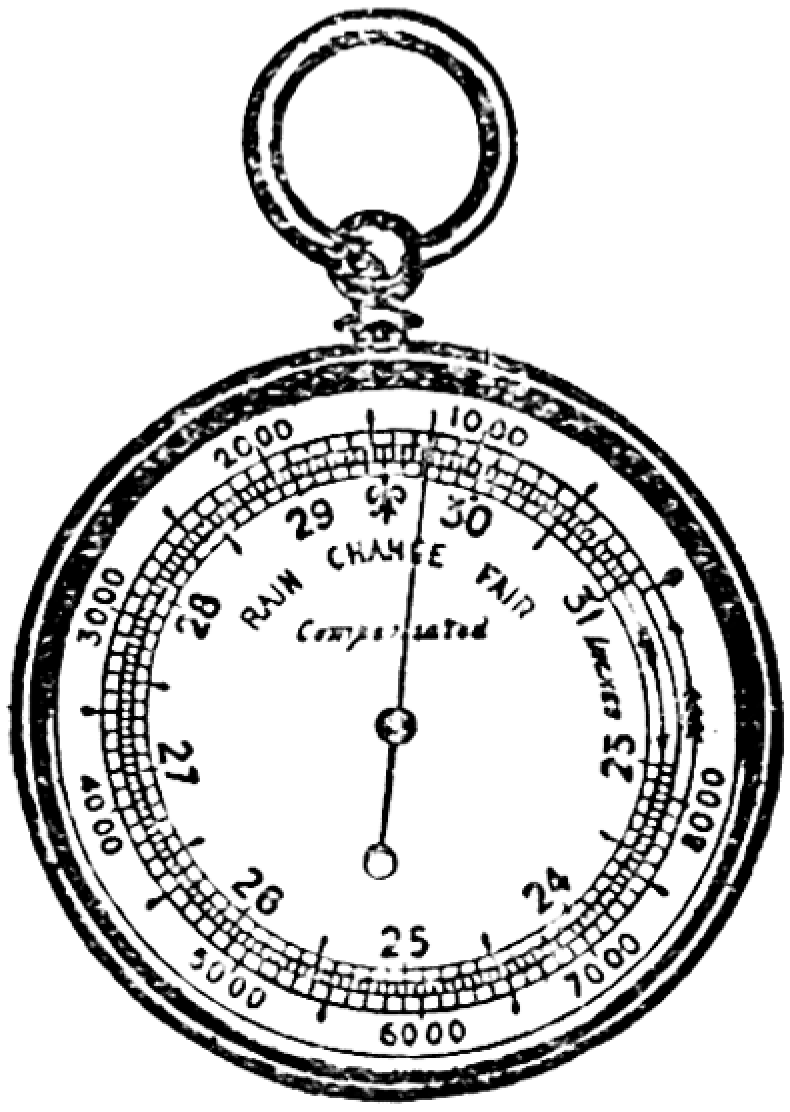


Fig. 28.

(1) Plot on a squared paper the daily readings of any place for a month. In considering the vertical scale for the graph, notice that the greatest quantity to be shown lies betwhen 28—32 inches and even less. Hence it is best to work suitably with a magnified vertical scale. This of course will hide the remarkable constancy of barometric height.

(2) *Frequency Diagrams.* It is often instructive to represent by diagrams the relative frequencies of different pressures. Look through the barometer records to be treated in this way and pick out the greatest and the least numbers that occur. Down the left-hand margin of the graph paper write these numbers from the highest to the lowest at intervals of 0·1 (*e.g.*, 30·5, 30·4, 30·3, etc....); write the number of times along the horizontal. Now read through the barometer returns and score opposite the numbers how often each occurs. Join these points by a zig-zag line.

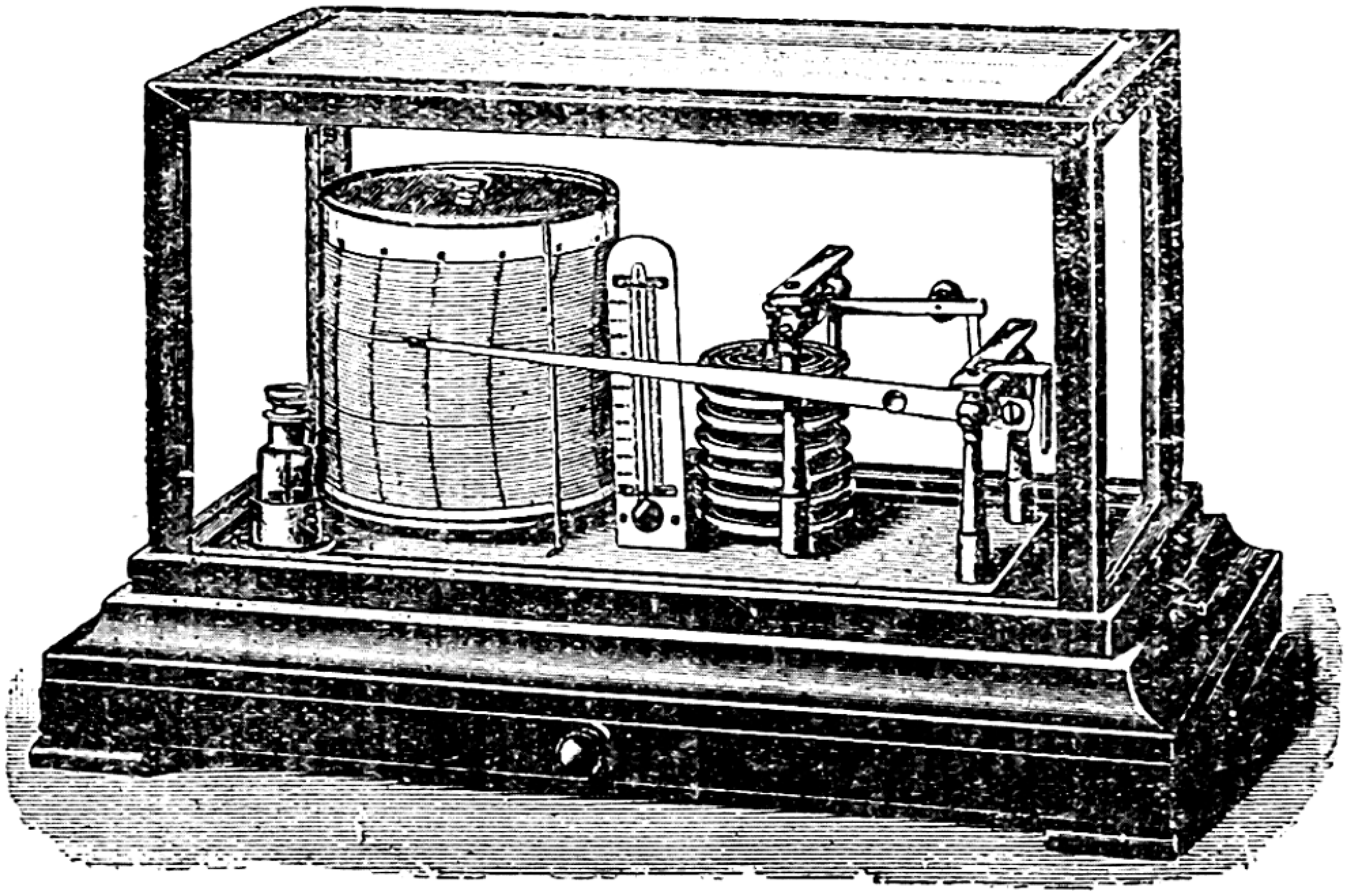


Fig. 29.

**55. Isobars.** Isobars are lines joining together places of the same pressure reduced to sea-level. Isobars do not necessarily follow contour lines. The pressure is observed at many meteorological stations and then the isobars are approximately drawn from the observations after reducing the pressure readings to sea-level. These isobars represent the horizontal pressure gradient, *i.e.*, the rate at which the pressure varies with distance in any direction at the earth's surface. Just as contour lines indicate differences of level and therefore slopes, similarly isobars indicate pressure slopes down which winds tend to blow. The line of steepest pressure-slope crosses the isobars at right-angles. It must be borne in mind that pressure readings at high altitudes must be reduced to sea-level. Say the pressure observed at Dharampore (height 4,406 ft.) is 24·47 in. The pressure at sea-level would be 1 inch higher for every 900 ft. of altitude. Hence the correction is +4·89 in. Therefore the pressure plotted on the map would be $24{\cdot}47+4{\cdot}89=29{\cdot}36$ in.

**56. Barometric Gradient.** The horizontal barometric gradient is the rate of fall of barometric pressure measured at right angles to two isobars. The unit is a fall of 1/100 inch in 15 nautical miles.

**57. Units.** The primary units of length, mass and time are the centimetre, gramme, and second respectively. The unit of pressure on this system is the *dyne* per square centimetre.

If $h$ cm. = height of a column of mercury,
$D$ = the density of mercury,
and $g$ = the acceleration due to gravity,
then the pressure due to the column $h = hDg$ dynes per sq. cm.
∴ The pressure due to a column of mercury 76 cm. long
$= 76 \times 13{\cdot}6 \times 981$
$= 1{,}013{,}200$ dynes per sq. cm.

*Or* approximately one million dynes per sq. cm.

This pressure of one million dynes is known as **Bar.**

The *millibar*, the unit employed for practical purposes by meteorologists is the *thousandth* part of the Bar.

Thus the normal pressure, *i.e.*, 760 mm. of mercury = 1,013·2 millibars.

### 58. Important Terms Connected With Weather Maps :—

**Cyclones.** A cyclone or depression is a region of low pressure surrounded by zones of higher pressure. The isobars are roughly circular or oval with the lowest pressure inside. The weather in a cyclone is very varied. It is often wet and stormy. A cyclone usually moves in the direction of the prevailing winds.

**Anticyclones.** An anticyclone is a high-pressure area surrounded by belts of low pressure. The weather associated with an anticyclone is usually quiet. There may be a slight drizzle but rain seldom falls in a well-marked anticyclone. The sky is usually clear though it is not essential. There may be small clouds in the afternoon which may disappear by evening.

**Secondary Depression.** A secondary depression is a low-pressure system contained in a larger one.

**Col.** A col is a central region between two high and two low pressure areas. It is a region of calm. The conditions are neither cyclonic nor anticyclonic.

**The Wedge.** A wedge is a region of high pressure where the isobars take the form of an inverted V. It is usually a region of fine weather and good visibility.

### WIND

**59. Wind.** Most of the observations of wind with which meteorologists have to deal are estimates of its force made on what is known as the Beaufort Scale, which is reproduced below.

### 60. The Beaufort Scale of Wind Force:

| Beaufort Number. | Beaufort's General Description of Wind. | Specification for use on Land, based on observations made at Land Stations. | Mean Velocity Miles per hour. |
|---|---|---|---|
| 0 | Calm | Calm ; smoke rises vertically ... | 0 |
| 1 | Light air | Direction of wind shown by smoke drift ... | 2 |
| 2 | Light breeze | Wind felt on face ; leaves rustle | 5 |
| 3 | Gentle breeze | Leaves and small twigs in constant motion ; wind extends light flag ... | 10 |
| 4 | Moderate breeze | Raises dust and loose paper ; small branches are moved ... | 15 |
| 5 | Fresh breeze | Small trees in leaf begin to sway ; crested wavelets on inland waters ... | 21 |
| 6 | Strong breeze | Large branches in motion ; whistling heard in telegraph wires ... | 27 |
| 7 | Moderate gale | Whole trees in motion ; inconvenience felt when walking against wind ... | 35 |
| 8 | Fresh Gale | Breaks twigs off trees; generally impedes progress ... | 42 |
| 9 | Strong gale | Slight structural damage occurs (chimney pots and slates removed) ... | 50 |
| 10 | Whole gale | Seldom experienced inland ; trees uprooted ... | 59 |
| 11 | Storm | Very rarely experienced inland ; accompanied by wide-spread damage ... | 68 |
| 12 | Hurricane | ... ... ... ... ... | Above 75 |

**The Beaufort Wind Scale (1936)**

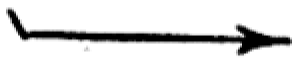
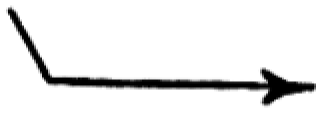
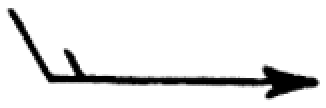
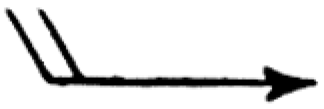
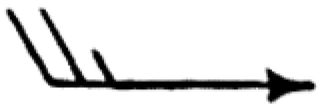
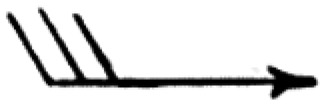
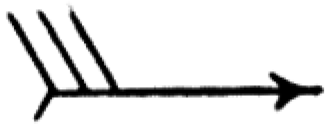
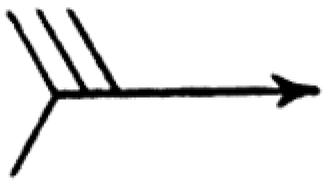
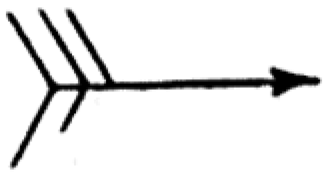
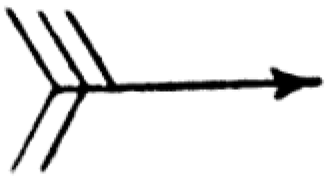
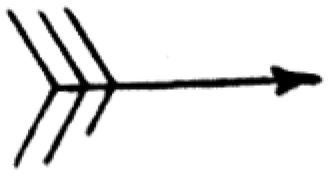
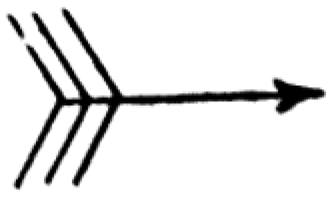
| NUMBER | WIND | NOTATION |
|---|---|---|
| 0. | Calm | ⊙ |
| 1. | Light air |  |
| 2. | Light breeze |  |
| 3. | Gentle breeze |  |
| 4. | Moderate breeze |  |
| 5. | Fresh breeze |  |
| 6. | Strong breeze |  |
| 7. | Moderate gale |  |
| 8. | Fresh gale |  |
| 9. | Strong gale |  |
| 10. | Whole gale |  |
| 11. | Storm |  |
| 12. | Hurricane |  |

Fig. 30.

In Indian Daily Weather Report a different scale of Wind force is used which is always appended to the map.

## BEAUFORT NOTATION

| | |
|---|---|
| b | blue sky (not more than quarter covered). |
| bc | sky partly cloudy (one-half covered). |
| c | generally cloudy (three-quarters covered). |
| o | overcast sky. |
| d | drizzle. |
| f | fog. |
| h | hail. |
| KQ | line squall |
| l | lightning. |
| m | mist. |
| p | passing showers. |
| q | squalls. |
| r | rain. |
| rs | sleet, *i.e.*, rain and snow. |
| s | snow. |
| t | thunder. |
| v | unusual visibility. |
| w | dew. |
| x | hoar frost. |
| y | dry air : humidity less than 60 per cent. |
| z | dust haze ; the turbid atmosphere of dry weather. |

## 61. Weather Symbols:—

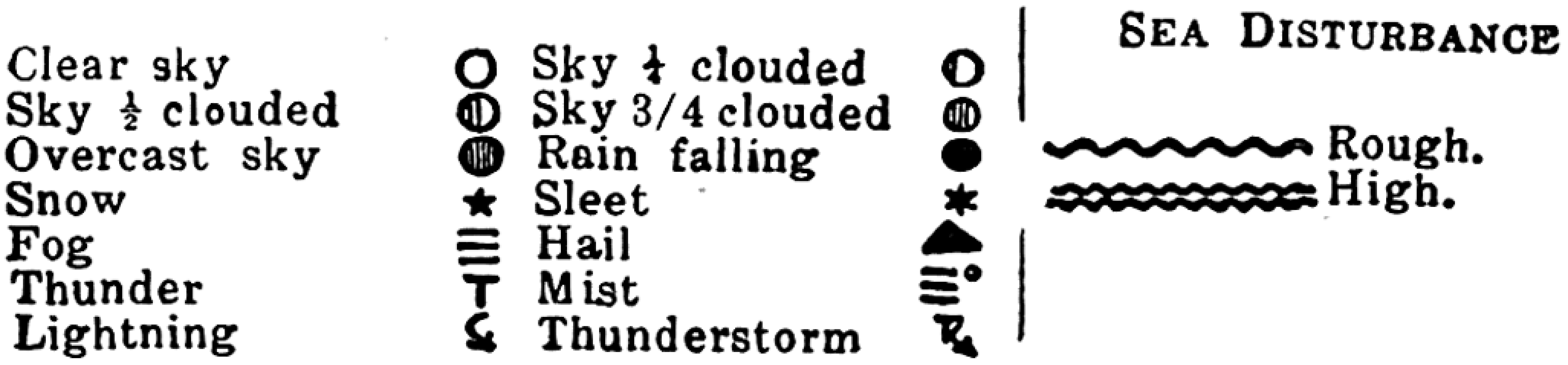


Fig. 31.

Capital letters indicate intensity, suffix$_0$ indicates slight and repetition of letters indicates continuity, thus :—

R = heavy rain, rr = continuous moderate rain, $r_0r_0$ = continuous slight rain.

*Barometer*--Isobars are drawn for intervals of two millibars.

*Wind* direction is shown by arrows flying with the wind.

Force on the scale *O*—12 (as above) is indicated by the number of feathers.

Mean velocity is shown in miles per hour by figures in small circles.

Temperature is given in °F.

**62. Anemometer.** This is a simple instrument for measuring the force of wind. In Robinson's cup anemometer, the wind causes the spin of a suitably poised vane, like a windmill spinning in a horizontal plane. The wind speed is measured by counting the number of rotations in a given time. The record gives the run of the wind in a fixed time, say an hour. This instrument is not suited for rapid fluctuations of wind.

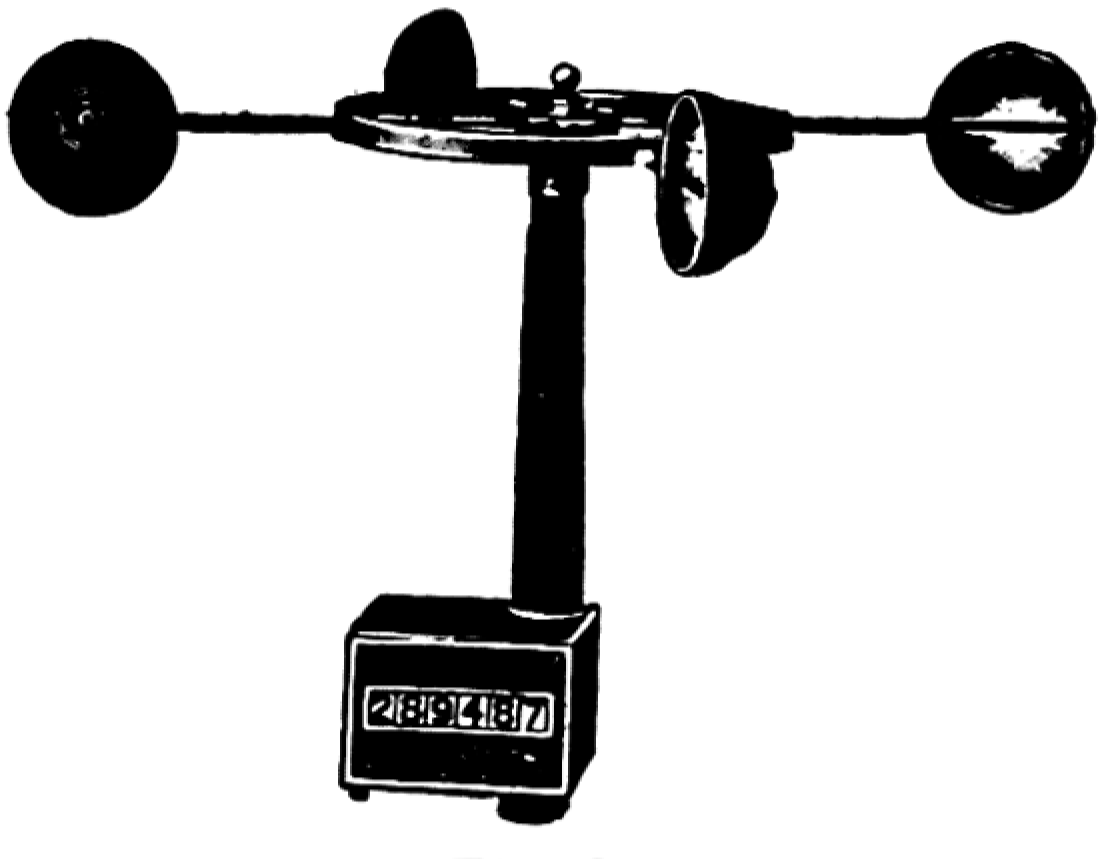


Fig. 32.

A more useful record is given by the more modern Dine's pressure-tube anemometer which has at many places displaced the cup anemometer. In **Dine's Anemometer** advantage is taken of the fact that the air in blowing over the obstacle produces small differences of pressure on various sides of the obstacle, which are capable of exact measurement, and afford information of the velocity of the wind. The "head" consists of a piece of tube open at one end which end is kept facing the wind by a vane. The wind blowing into the tube

Besides a daily apparent movement from east to
due to daily rotation of the earth, it is easy to notice

produces an excess of pressure within it. There is also a piece of tube placed vertically, pierced by a ring of small holes. The wind blowing on these holes produces a slight decrease of pressure inside. These differences of pressure are communicated by tubing to the place where the recording of the instrument is placed.

**63. Exploration of the upper Air.** The systematic exploration of the upper air is carried out with kites and balloons. Small indiarubber balloons are filled with hydrogen and allowed to drift with the wind. They are watched through the telescope of a theodolite until they either burst or are lost to view. The azimuth and elevation of the theodolite are noted at short intervals.

### TEMPERATURE

**64. Temperature.** From the sun there emanates in every direction what is called *radiant energy*; only a small portion of this energy is intercepted by the earth and manifests itself, in heat, light or as the cause of certain chemical and electrical effects. Air, water and the crust of the earth behave differently towards solar radiation or as it is called *insolation*. When matter is heated it expands; in the case of air and water, this leads to convection currents. The earth represents two kinds of surface to solar radiation :—

(*i*) The rock, which heats up readily, and

(*ii*) Water, which heats up slowly.

The air is scarcely heated directly as air allows practically all the solar rays to pass through it unabsorbed.

**Experiment.** Take two thermometers. Place one in the sun and hold the other in your hand and move it to and fro. The temperature of the former will be higher than that of the latter.

The lowest layer of the air in contact with the earth is warmed by contact with the earth's surface.

The cause of the varying temperature throughout the year is the alteration of the altitude of the sun, brought about by the inclination of the earth's axis to the plane of the ecliptic. The distance from the earth to the sun has very little to do with the matter.

**65. Temperature of the Air.** The temperature of the air is ascertained from the reading of a mercury thermometer. The thermometer must give the temperature of the air surrounding it, and must not be exposed to direct sunshine. The thermometers are placed in a screen or box with louvred sides made of wood and painted white. See Fig. 33. In certain Meteorological Observatories in India the thermometers are placed in huts to secure more ample ventilation.

Temperatures of the upper air are measured by self-registering balloons, *i.e.*, unmanned balloons to which self-registering instruments are attached.

**66. Maximum and Minimum Thermometers.** At observing stations in different places the temperature recorded by a thermometer is read two or three times every day. In most observatories, however, two special thermometers are used, one of which records the lowest temperature during the day and night (known as the *minimum thermometer*), and the other which records the highest temperature during the same period (known as the *maximum thermometer*). The instrument is set at 8 a. m. daily.

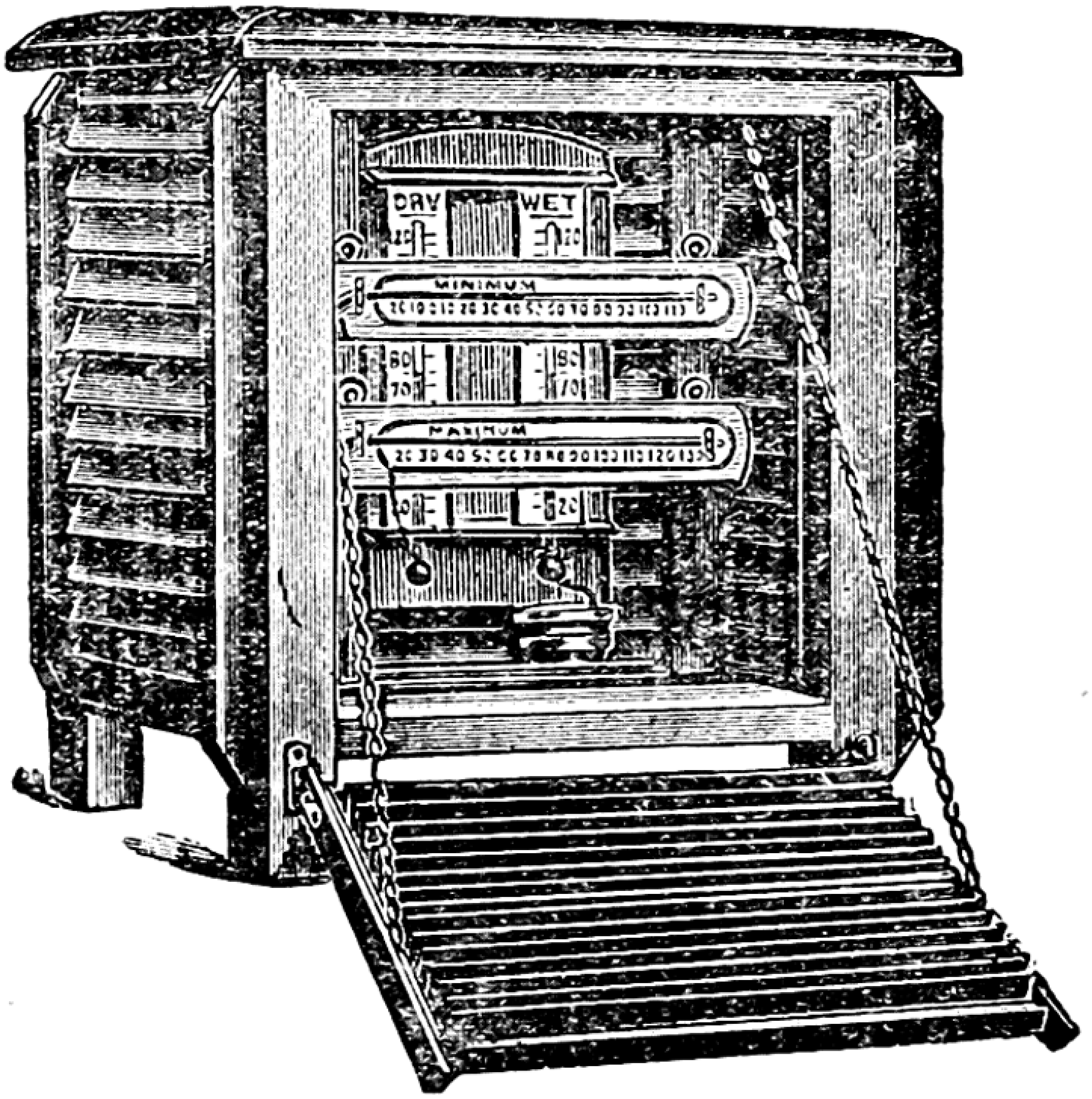


Fig. 33.

The *maximum thermometer* is filled with mercury and the tube contains an iron index. The index is pushed forward to the furthest point reached by the mercury and left there when the mercury recedes again since mercury does not wet iron. The *minimum thermometer* is filled with alcohol in which a glass index is immersed. The index is pulled to the lowest point reached by the alcohol and is left there when the thermometer rises. When the temperature rises the alcohol flows past the index but does not move it. Both thermometers are mounted on the same board. See Fig 34.

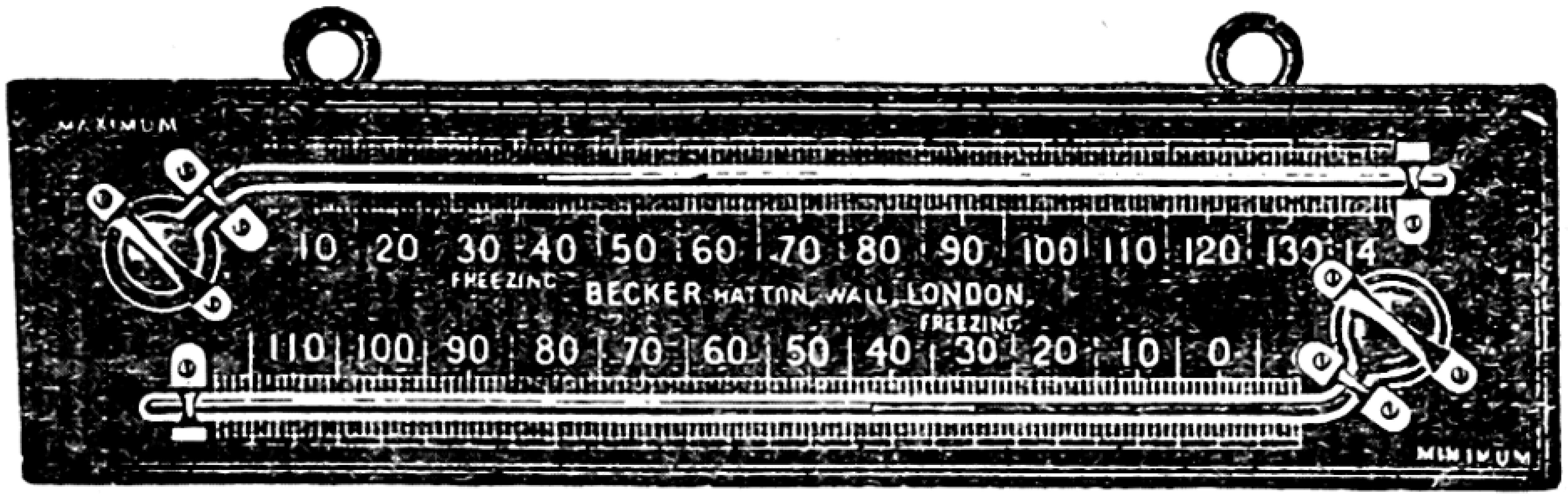


Fig. 34.

**67.** A **Thermograph** is a self-registering thermometer. See Fig. 35. A strip composed of two metals with different coefficients of expansion by heat is fixed at one end and connected at the other to a pencil marking on a drum rotated by clock-work. Alterations in temperature cause the pencil to rise or fall, leaving a permanent record.

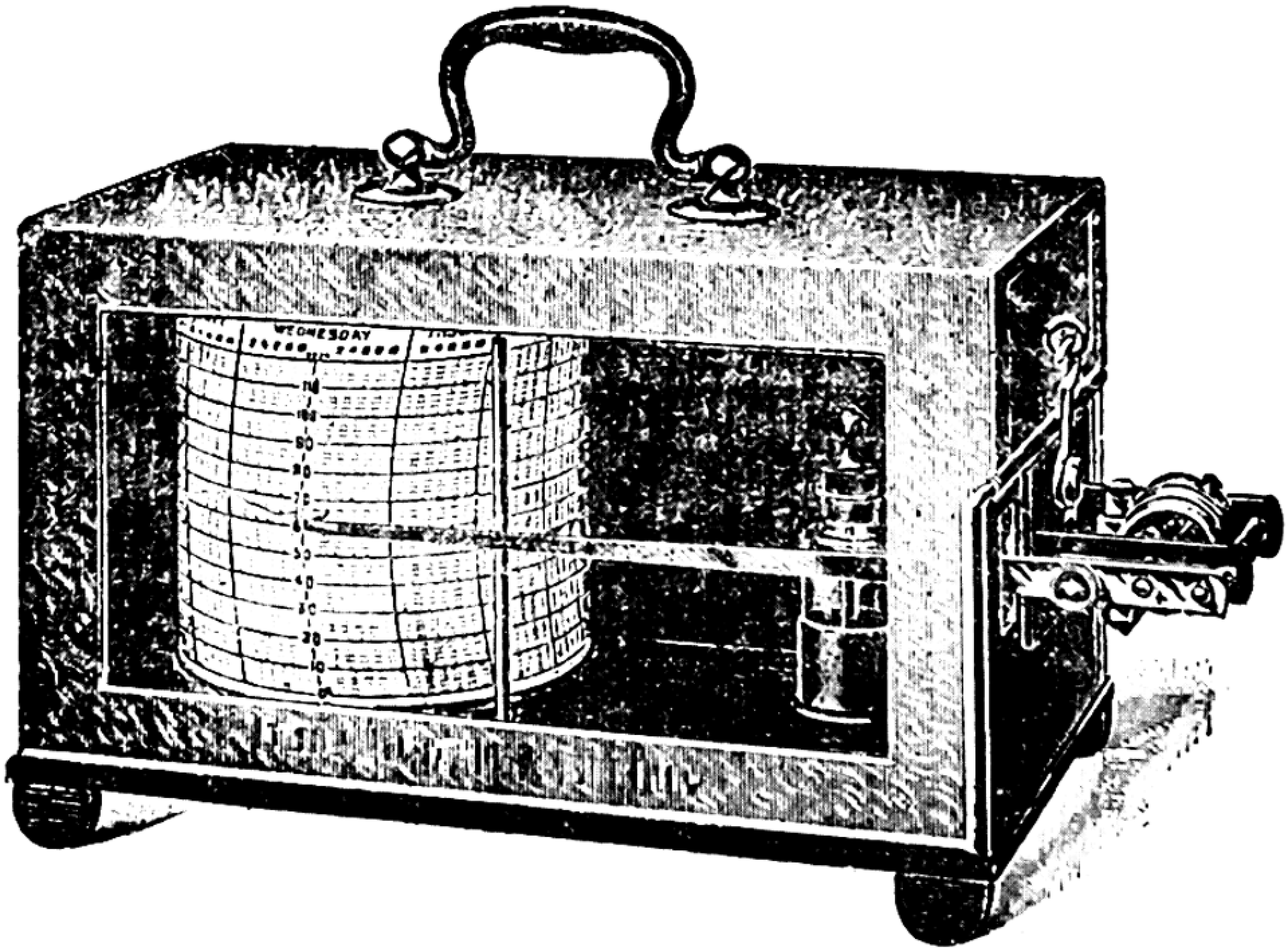


Fig. 35.

**68. Mean Temperature.** The mean temperature is obtained from the maximum and minimum temperature, *e.g.*,

Observations made during the 24 hours ending at 8 a.m. on May 26th, 1942.

| Station | Max. temp. | Min. temp. | Mean temp. |
|---|---|---|---|
| Bombay ... ... | 94 | 83 | 88·5 |
| Calcutta ... ... | 102 | 83 | 92·5 |
| Delhi ... ... | 106 | 69 | 87·5 |
| Karachi ... ... | 89 | 82 | 85·5 |
| Lucknow ... ... | 108 | 76 | 92·0 |
| Madras ... ... | 103 | 86 | 94·5 |
| Nagpur ... ... | 111 | 89 | 100·0 |
| Patna ... ... | 101 | 82 | 91·5 |
| Peshawar ... ... | 93 | 69 | 81·5 |
| Poona ... .. | 99 | 74 | 86·5 |
| Simla ... ... | 71 | 50 | 60·5 |
| Srinagar ... ... | 66 | 49 | 57·5 |

Mean temperature must be distinguished from *average mean temperature.* If the mean temperatures obtained for a certain day are compared with similar results on the corresponding day of other years, a difference is observed. Average of the mean temperatures of a given day for a number of years is called the average mean temperature for the period of years taken.

**69. Isotherms.** An isotherm is a line drawn on a map connecting places of the same mean temperature reduced to sea-level.

**70.** The **Annual Ranges of Temperature** is the *difference* between the mean temperatures of the hottest and coolest months of the year.

## EXERCISES

1. Represent graphically the maximum and minimum temperatures at any particular places for a given month. Plot the dates along the abscissa and the temperature as ordinates. The data can be obtained from the records of Meteorological Office. Mark the maximum temperature by a continuous line and the minimum by a dotted line.

2. Draw a graph of the mean temperature in Ex. 1 and mark it red.

3. Tabulate the mean average temperature for any month (say July) against various stations at which observations are made in India. Draw an outline map of India and mark the places with temperatures reduced to sea-level. Draw lines to represent the isotherms.

*N. B.*—When observation is made at a high station, a reduction should be made to sea-level as explained on page 41.

4. What is an Isobar? Draw various isobaric shapes studied by you in relation to Weather Chart. (*Punjab Univ., Inter., 1937*)

5. Draw a map of India? Show a winter cyclone with its centre at Lahore Number the isobars and show wind direction by means of signs used on Weather Charts. Briefly describe the weather associated with such a cyclone. (*Punjab Univ., Inter., 1937*)

6. What is an isotherm? How is it drawn? Bring out the principles on which an isothermic map is drawn with special reference to weather maps of India. (*Punjab Univ., Inter., 1938*)

# CHAPTER VIII

## WEATHER MAPS—II

**71. Clouds.** The study of clouds is a most fascinating one. It appeals equally to the artist and the scientist. Clouds are full of meaning for the army airman. The study of clouds includes the following :—

(*i*) Their form and type ; simple outline and open shading will fully suffice in depicting them.

(*ii*) A knowledge of their altitudes.

(*iii*) Their weather meaning.

(*iv*) The direction from which the cloud comes.

**72. Classification.** There are three principal types of clouds :—

(*a*) *Cirrus* type, of fibrous or feathery appearance.

(*b*) *Cumulus* type, having rounded tops

(*c*) *Stratus* type arranged in horizontal layers or sheets.

The intermediate types* are indicated by combining the names of these primary types These sub-types are classified into the following groups according to their average altitudes :—

(*i*) **Upper Clouds** (altitude 30,000 feet).

1. *Cirrus*. Light, fleecy, feather-like and fibrous stretching right across the sky. Composed of ice crystals. Often forecasts an advancing cyclone. (Abbrevation Ci.)

2. *Cirro stratus*. A thin whitish sheet of cloud often covering the sky. (Abb. Ci-St.)

(*ii*) **Intermediate Clouds** (altitude between 10,000—23,000 ft.)

3. *Cirro-cumulus.*—Small globular masses in groups or line. They cast no shadows. Indicate fine weather and are composed of ice crystals. (Abb. Ci-Cu.)

4. *Alto-cumulus.*—Groups of large globular masses of white or grey clouds near the centre. Their edges appear confused. (Abb. A-Cu.)

5. *Alto-stratus.*—A thick sheet of a grey or bluish colour sometimes forming a compact mass of dark grey colour. (Abb A-St.)

(*iii*) **Lower Clouds.** (Altitude 6,500 feet).

6. *Strato-cumulus.*—Large globular rolls of dark clouds, frequently, extending right over the whole sky, especially in winter. (Abb. St-Cu.)

7. *Nimbus.*—The "rain cloud." A thick layer of dark clouds, with rugged edges from which steady rain or snow is usually falling. (Abb. Nb.)

(*iv*) **Clouds of Diurnal Ascending Currents.** (Altitude 4,500 to 6,000 feet.)

8. *Cumulus.*—"Woolpack" clouds Thick clouds of which the upper surface is dome-shaped and the base is horizontal. (Abb Cu.)

9. *Cumulo-nimbus.*—The "storm" or "thunder clouds." Heavy masses of clouds rising in the form of mountains or turrets. Rain, snow or hail are precipitated from the base. (Abb. Cu-Nb.)

(*v*) **High Fogs.** (Altitude below 3,300 ft.)

---

*May be omitted by Intermediate students of the Punjab University.

10. *Stratus.*—Low, dense, heavy clouds in horizontal sheets or layers of lifted fog, formed by condensation. Seen at sunset and early morning and usually a fine-weather cloud, indicating quiet settled conditions. Sometimes the cloud forms a gloomy canopy over the whole sky or descends as a frog, requiring a wind to lift it. (Abb. St.)

To indicate that a cloud is broken, the qualification *fracto* may be applied to these terms thus fracto-cumulus. The Frontispiece gives illustrations of various cloud forms, with their names.

**73. Sunshine Recorder.** This consists of a sphere of crown glass 4 inches in diameter and 3 lb. in weight, supported on a pedestal in a metal zodiacal frame. It must be fixed in such a position that the sun can shine on it the whole of the time it is above the horizon. A prepared card is inserted in the groove behind the ball. The sun when shining burns away or chars the surface at the points on which its image falls. The card is removed after sunset and a new one inserted.

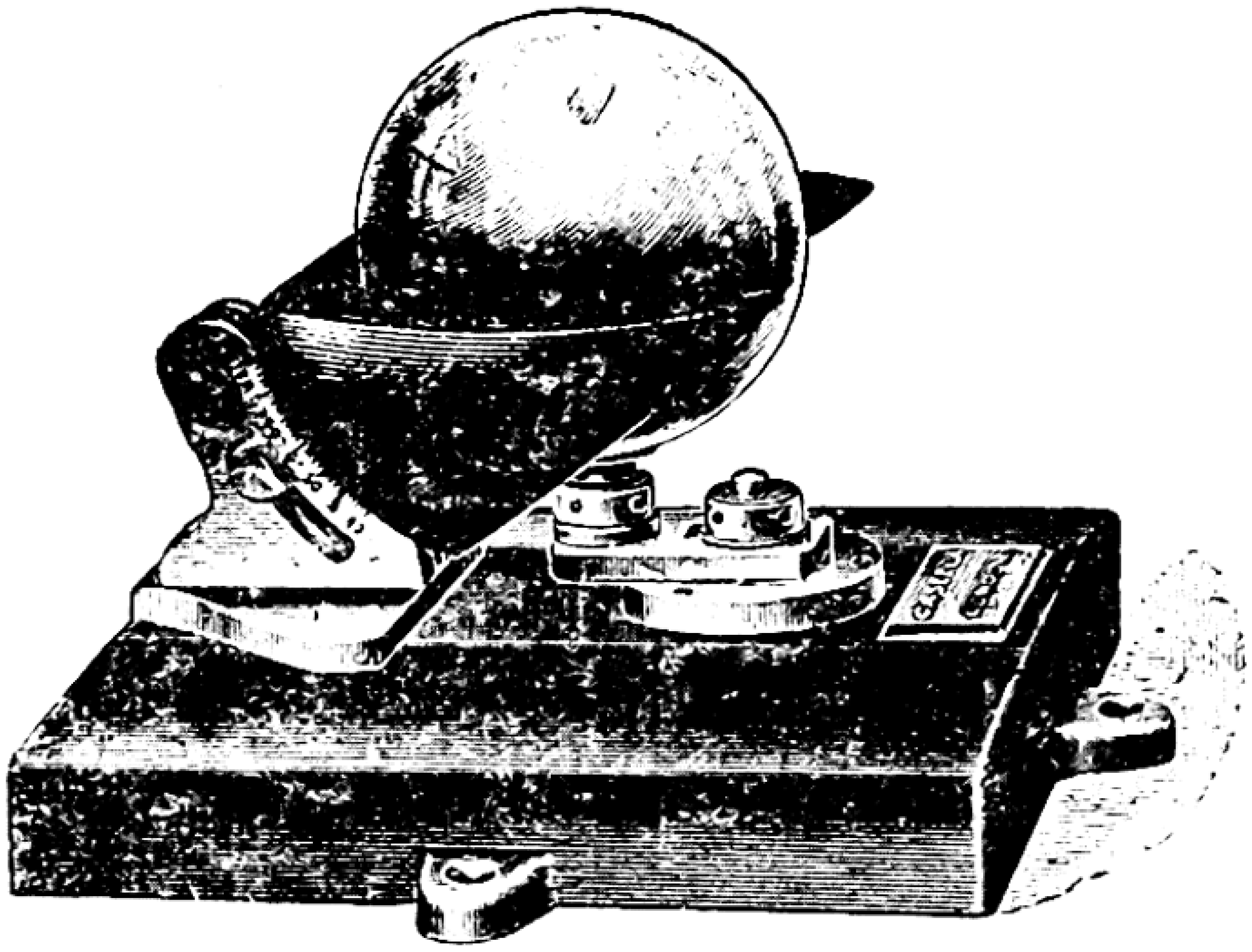


Fig. 36.

**74. Rainfall.** The amount of the rainfall of a place is measured in terms of the depth in inches to which the land would be covered if no rain sank in the ground and if none ran off or was lost by evaporation.

**75. The Rain-gauge.** The rain-gauge is a simple instrument for measuring the amount of rainfall.

Take a glass funnel and a cylinder of exactly the *same* diameter. Fit the funnel in the cylinder; this will form a rough gauge. Take a small flat bottomed cylinder and paste a vertical strip of paper AB on it. Pour water in the large cylinder till its depth is just 1 inch (measured by the ruler held vertically inside the cylinder). Transfer this water to the narrow cylinder. Draw a line on AB at the surface of the water and mark it 1 in. Sub-divide this height into tenths. Note that the graduated cylinder can only be used for the particular gauge for which it is made.

The student can make a simple rain-gauge for himself from a jam-jar and a small cylinder. If the funnel is of greater diameter than the jar, the above method will not do. The height in this case must be found by calculation.

Let A, R, D be the area, radius and diameter of the funnel, and $a$, $r$, $d$, the area, radius and diameter of the cylinder, and let $h$ be the height of water in the cylinder.

Volume of water in large cylinder or jar = Volume of water in small cylinder

$$1 \text{ in} \times A = h \times a$$

$$\therefore \quad h = \frac{A}{a} = \frac{\pi R^2}{\pi r^2} = \frac{R^2}{r^2} = \left(\frac{D}{d}\right)^2$$

Thus $\left(\frac{D}{d}\right)^2$ gives the number of inches that the 1 inch mark must be drawn above the bottom of the cylinder.

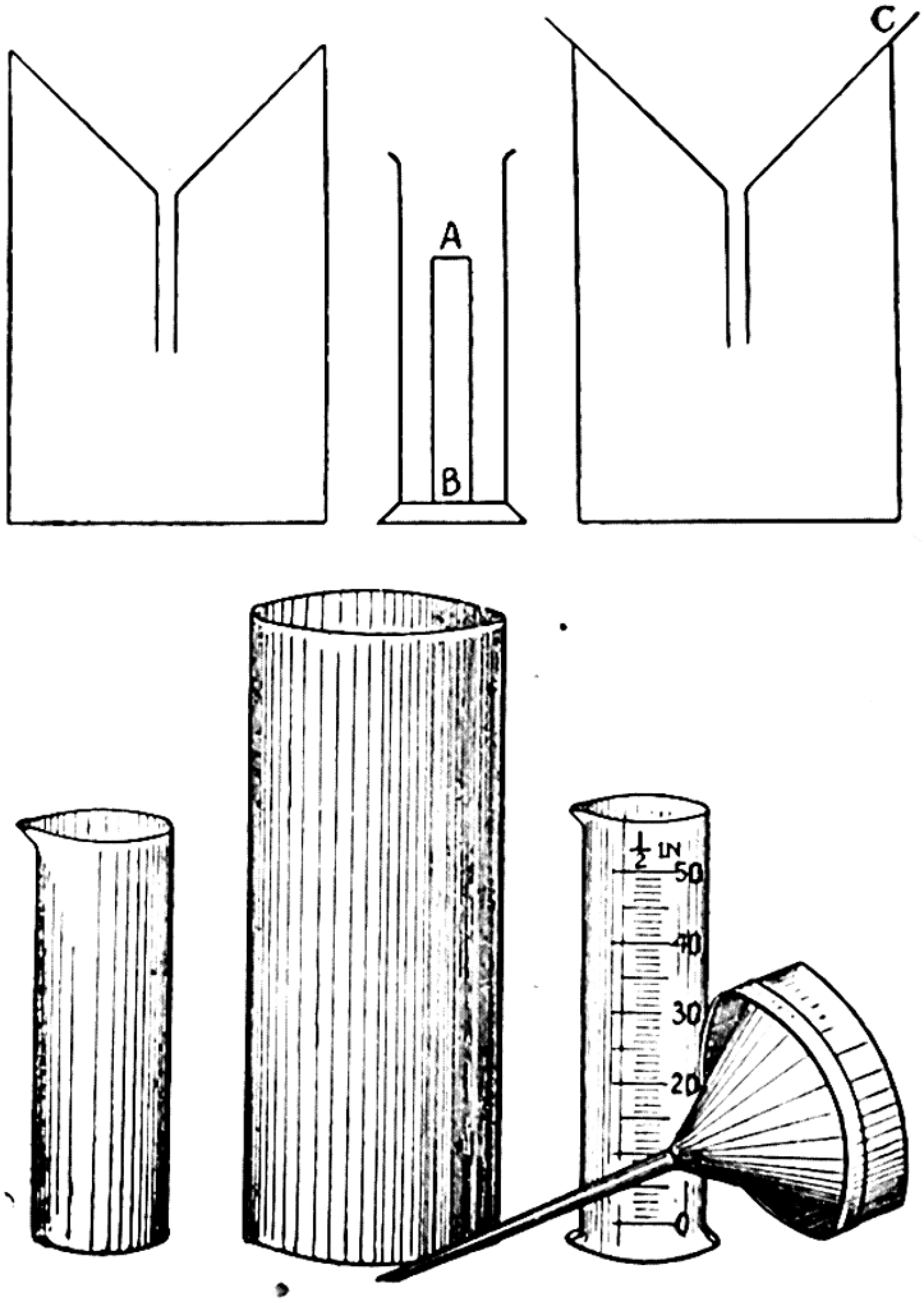


Fig. 37.

**76. Plotting of Rainfall Statistics.** When the rainfall is measured daily, we often find an abrupt change from day to day. It is generally represented by shaded rectangles, the heights of which stand for the amount of rain (Fig. 38).

Rainfall graphs may be plotted on the same principle as the graphs for pressure and temperature, except that the points are joined by straight lines and not by smooth curves. This is because temperature and pressure are continuous, while rainfall is a discontinuous phenomenon.

Rainfall and temperature graphs should be plotted on separate diagrams.

If the rainfalls for all the days of a month are added together, we obtain the *monthly rainfall* of a place; similarly the *annual rainfall* for the whole year. If we take the average of the rainfall for corresponding months of a number of years, we obtain the *mean monthly rainfall* for that period of time.

**77.** *Rainfall Maps.* Rainfall maps are usually provided with a table of th style of shading to indicate the varying amounts of rainfall.

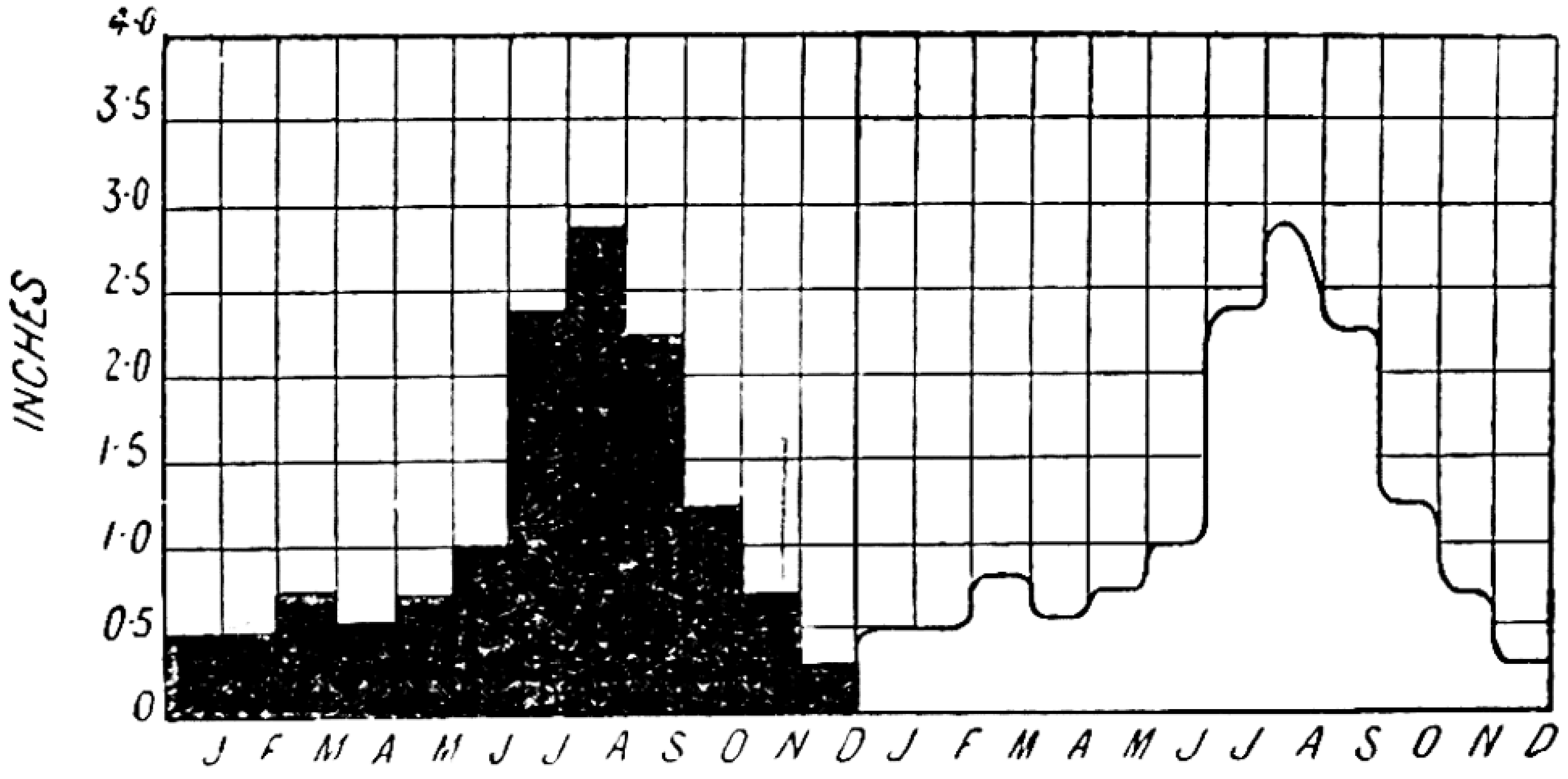


Fig. 38.

**78. Moisture in the Air.** Water vapour is always present in the atmosphere in variable amounts. Evaporation is continuously going on from every surface of water even when the weather is cold ; otherwise the dhobi would not be able to get his washing dried outside in the air. The rate of evaporation depends upon (*a*) the temperature of the air, and (*b*) the amount of water vapour already present in the air.

When a certain space has taken up all the vapour it can, it is said to be *saturated.* If the temperature of the space rises, it can take up more water vapour and thus become *unsaturated.* If the temperature falls, the amount of water vapour that the space can hold decreases ; if the space is saturated, some of the vapour will condense. The temperature at which condensation of water vapour to liquid water takes place is called the *dew point.*

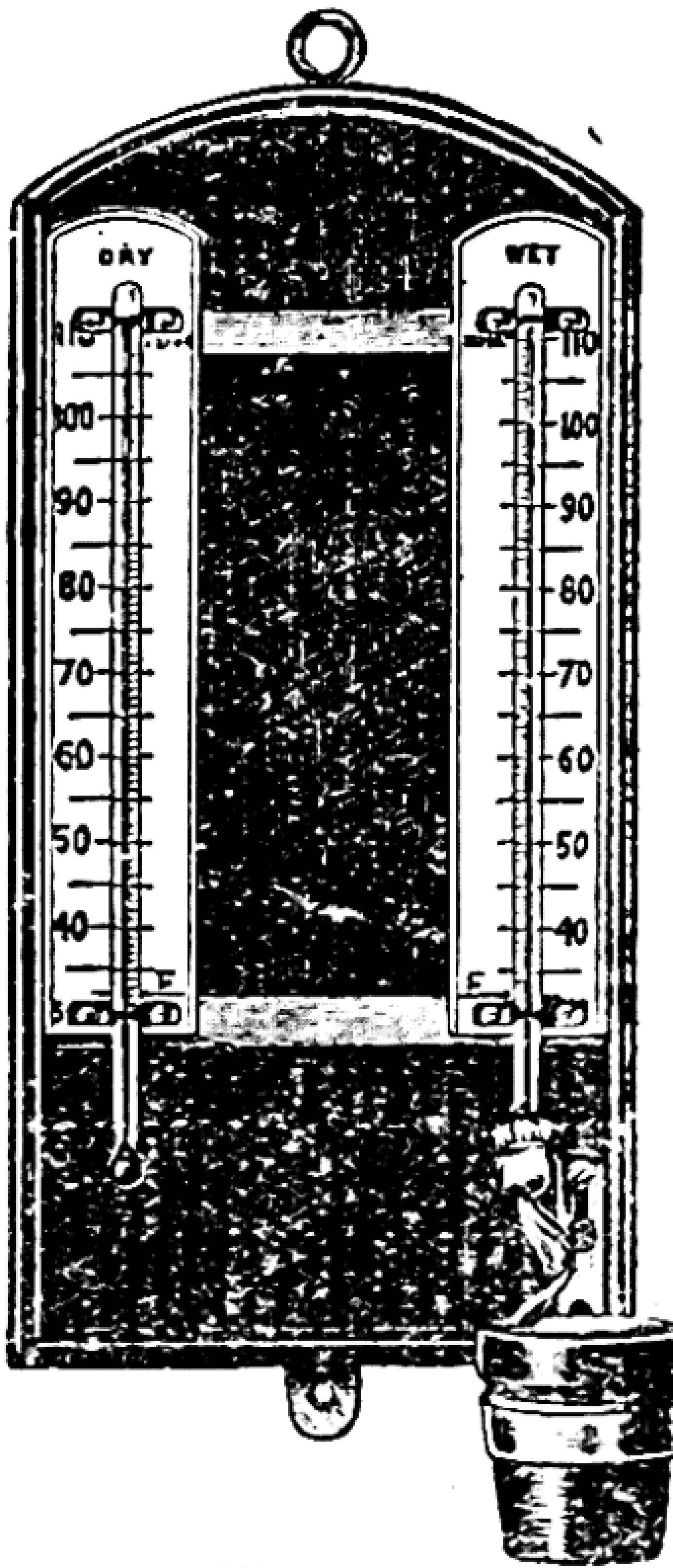


Fig. 39.

**79. Wet and Dry Bulb Thermometers.** Take two thermometers precisely alike and fix them side by side on a board. Cover the bulb of one with muslin or a piece of cloth, the outer end of which is dipping in a small beaker, or a tin can containing water. The temperature of the wet bulb thermometer will always be lower than that of the other when evaporation is going on from its surface. Take the readings of the two thermometers. Find by subtraction the difference in temperature between them. This difference determines the saturated or unsaturated state of the atmosphere.

Care should be taken to keep the beaker filled with distilled water. The muslin should be changed once a month. In damp weather the dry bulb thermometer should be wiped a few minutes before observation.

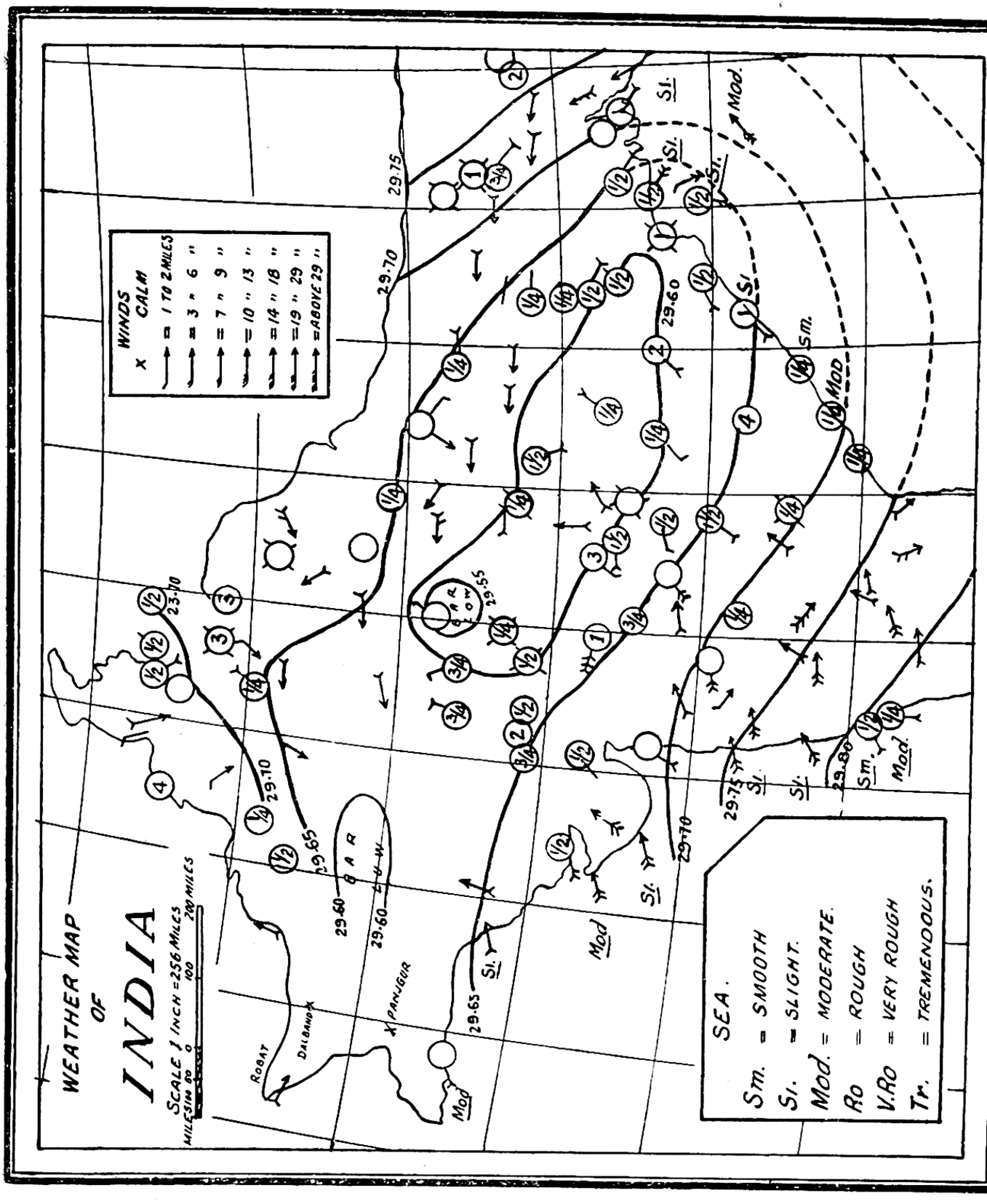
**80. Meteorological Records.** The student is now in a position to keep a monthly record of meteorological observations which should be arranged in columns as shown below :—

*Place*..................................
*Month*................................*19* .
*Height above sea-level*............*feet.*

| Date. | Barometer Reading. | Wind. | Rainfall in inches. | Type of clouds, if any. | THERMOMETER. | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Max. | Min. | Wet. | Dry. |
| | | | | | | | | |

**81. The Indian Daily Weather Report.** The weather map gives a succinct summary of the weather conditions over a large area and is based upon observations made at a number of stations and collected together at a central office. The Indian Daily Weather Report can be obtained from the office of the Director General of Observatories at Poona. The weather notations adopted have been explained in the preceding sections. Study the following questions :—

(1) What system of pressure distribution is shown? Observe if the isobars form a cyclone, anticyclone, a col, wedge or a secondary depression, etc. and note the weather you would expect at places where such formations occur. Study the departure of pressure from the normal.
(2) Where are the strongest winds experienced ? What kind of weather is being experienced there ?
(3) Where is rain falling ? and where is the weather fine ? How do you account for the presence or absence of rain in these places ? Tabulate the rainfall of a few important stations.
(4) Examine the departure of temperature from the mean.
(5) Study if the sea is smooth or rough, etc.
(6) What general inferences may be drawn for the day ?
(7) Study the weather maps for two or three consecutive days, observe how the pressure system moves and prepare a forecast for the following day.


WEATHER MAP OF INDIA
SCALE 1 INCH = 256 MILES
MILES 100 50 0 100 200 MILES
WINDS
X CALM
= 1 TO 2 MILES
= 3 " 6 "
= 7 " 9 "
= 10 " 13 "
= 14 " 18 "
= 19 " 29 "
= ABOVE 29 "
SEA.
Sm. = SMOOTH
Sl. = SLIGHT
Mod. = MODERATE
Ro = ROUGH
V.RO = VERY ROUGH
Tr. = TREMENDOUS.
29.75
29.70
29.65
29.60
29.55
29.10
29.80
BAR LOW
ROBAT
DALBANDIN
PANJGUR
Sl.
Sm.
Mod

(8) A useful exercise is to prepare a graph showing the pressure gradient from one place to another, say from Lahore to Madras.

## EXERCISES

1. Study the weather map of India for the following dates and record your observations:—

January 30th, March 18th, May 16th
July 15th, and 16th, August 18th, September 26th
October 25th and 29th, November 18th, December 11th.

2. Study the weather map of India for June 1st, to 4th and prepare a forecast for June 5th.

3. How are storms predicted in India? Illustrate by a diagram or a chart.

4. Point out the connection between areas of high and of low pressure and the direction of the wind. What influence has the rotation of the earth on winds? In what direction do winds blow that are most altered in direction thereby?

5. Analyse a typical weather map to show (*a*) what information can be derived from it; (*b*) what data would be required for its preparation.

6. Compare any two weather maps showing the weather conditions associated with cyclones and anticyclones (*a*) in winter (*b*) in summer.

7. How are weather forecasts made? What unforeseen factors may possibly interfere with the forecast?

8. Examine a map of India, which shows isotherms for January and July; draw lines of equal annual range of temperature. Comment on any points of special interest.

9. In what respects does an isothermal map and an isobar map (*a*) resemble (*b*) differ from, a contoured map? What adjustment of data is necessary before preparing isothermal and isobaric maps?

10 The following is the record of the monthly distribution of temperature and rainfall of a place in India. Represent it graphically and locate the place :—

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp. (F) | 75·3 | 76·6 | 79·9 | 84·1 | 88·7 | 88·4 | 85·7 | 84·5 | 83·9 | 80·8 | 77·9 | 75·7 |
| Rainfall | 1·1 | 0·3 | 0·3 | 0·6 | 1·8 | 2·0 | 3·8 | 4·5 | 4·9 | 11·2 | 13·6 | 5·4 |

**(*Punjab Univ., Inter., Supp. 1932*)**

11. Describe exactly how the material obtained by the Meteorological Office, Poona, is plotted to form the daily weather map of India. What information can be had from this map?
**(*Punjab Univ., Inter., 1934*)**

12. Draw a map of India and show—
(*a*) a Bay cyclone (July) with its centre near Calcutta.
(*b*) Number of isobars, wind directions, and probable areas of cloud and rainfall.
**(*Punjab Univ., Inter., 1935*)**

13. What is a weather chart? How is it prepared? What information is to be had from the chart?
**(*Punjab Univ., Inter., 1936 & Supp. 1937*)**

14. Give the principal features of the Indian Daily Weather Report to show your familiarity with it. Where is it published and how is the data collected?
**(*Punjab Univ., Inter., Sept. 1941*)**

# CHAPTER IX

## MAP PROJECTIONS—I

**82. Introductory.** There are many surfaces which are not plane but they can be unrolled or "developed" into plane surfaces without stretching in any direction provided they are made of thin material, *e.g.*, paper or thin metal sheet. For instance, a cylindrical tube, if cut from end to end, can be laid out flat to form a plane surface. A cone is another surface which can be developed by cutting from its point to its base.

A great majority of curved surfaces cannot be unrolled into planes; they are known as " undevelopable surfaces." For instance, it is impossible to fit a sheet of paper to the surface of a round ball. The sphere, therefore, is undevelopable.

An ordinary geographic globe (12 in. diameter) represents the reduced earth and its shape is very nearly spherical. We cannot lay a sheet of tracing paper on a globe to fit it closely everywhere without innumerable folds and creases. If the surface of the earth were developable, we would not have had to study map projections. As it is, we have to study different methods used for transfering the lines of latitude and longitude from the globe to a flat sheet of paper. A **Map Projection,** therefore, is a means of representing the lines of latitude and longitude of the globe ~~on a flat sheet of paper. The network of~~ latitudes and longitudes thus formed is called a *graticule.*

As stated above it is impossible to make a correct map of any portion of the globe; it is, however, possible to maintain certain definite qualities in a projection. These are as follows :—

1. Preservation of area.
2. Preservation of shape.
3. Preservation of scale.
4. Preservation of bearing.
5. Ease of drawing.

The student is familar with the following properties of a sphere.—

1. That every plane section of a sphere is a circle.

2. That the section through the centre is the largest circle that can be cut from a sphere. It is called a *great circle*; all other plane sections are called *small circles.*

3. That the small circles get smaller and smaller as the plane of section moves away from the centre of the sphere.

**83. Classification.** Various methods of projection may be classified in a general form as follows :

1. Cylindrical Projections
2. Conical Projections
3. Zenithal Projections
4. Conventional and Modified Projections.

(1) *Cylindrical Projections.* In these we may imagine a sheet of paper rolled into a tube-form and placed round a globe.

(2) *Conical Projections.* A sheet of paper rolled up to form a simple cone may be placed on a globe of convenient size. The cone could be placed in many positions, but the normal case, that gives a useful map, is the one in which the apex of the cone lies on the axis of the earth produced.

(3) *Zenithal Projections.* Imagine a source of light at the centre of the globe and assume the globe to be transparent. Place a sheet of paper at the North Pole. It will be found that the meridians are projected as straight lines and the parallels as circles. The paper may be made to touch the globe at any other point, but in all cases the features of the circle will be projected as shadows. Projections made in this way are called Zenithal or Azimuthal Projections.

(4) *Conventional Projections* include some greatly modified projections. These vary considerably in construction and appearance but are very widely used.

**84. Latitude and Longitude.** All places on the Earth's surface are defined by parallels and meridians, hence a map cannot be drawn unless these are first plotted. Latitude is defined as the angular distance north or south of the Equator. A *parallel of latitude* is an imaginary line drawn round the Earth parallel to the Equator and at a constant angular distance from it. Only one line of latitude, *i.e.*, the Equator, is a great circle ; all others are small circles.

A *meridian of longitude*, is a line passing entirely round the sphere and through the poles. All meridians are great circles.

Parallels and meridians intersect at right angles on the globe.

**85. Scale.** It is necessary to consider the scale in the construction of projections. Assume the earth to be a perfect sphere.

The radius of the earth = 3960 miles
= 3960 × 1760 × 3 × 12 inches
= 250,905,600 inches

Let us take this to be approximately
= 250,000,000 inches.

A globe of 1″ radius is 1/250,000,000th of the size of the earth. Hence for a projection on a scale = 1/250M we will take the radius = 1 inch and diameter = 2 inches.

We may similarly calculate that—

On a scale of 1 : 125,000,000, the radius of the globe = 2 inches.
,, 1 : 100,000,000 ,, ,, ,, = 2·5 in.
,, 1 : 10,000,000 ,, ,, ,, = 25 in.
,, 1 : 1,000,000 ,, ,, ,, = 250 in.

## CYLINDRICAL PROJECTIONS

**86.** In cylindrical projections we assume that the globe is surrounded by a cylinder which just touches it around the Equator or along any other great circle. These projections are very common in atlases. The parallels and meridians are first transferred from the sphere to the cylinder and then the surface of the cylinder is developed so that it becomes a flat sheet of paper. The lines can be transferred in several ways to be described presently, each under its proper name.

There are certain features which are common to all these projections :—

1. The cylinder touches the globe along the Equator or along any great circle, therefore the Equator or the particular great circle could be traced through.

2. It will give a circle on the cylinder parallel to the top and bottom. When the cylinder is unfolded, these circles will become straight lines equal in length to the Equator.

3. The distance between the meridians on the map at all latitudes is the same as that at the Equator.

We thus conclude that—

The meridians will be a series of parallel straight lines at right angles to the Equator and the parallels will be a series of straight lines parallel to the Equator.

**87. The Simple Cylindrical Projection.** In this, the principle adopted is that the distances from parallel to parallel should be *the same* on the map as they are on the reduced earth or globe. The parallels are drawn at their true distance apart so that the graticule becomes a series of squares.

**Construction of the Graticule.** Find the length of a meridian according to the required scale. Divide it truly. Draw the Equator at right angles to the meridian and equal to twice its length. Draw parallels parallel to the Equator and meridians as straight lines perpendicular to the Equator spaced at equal intervals.

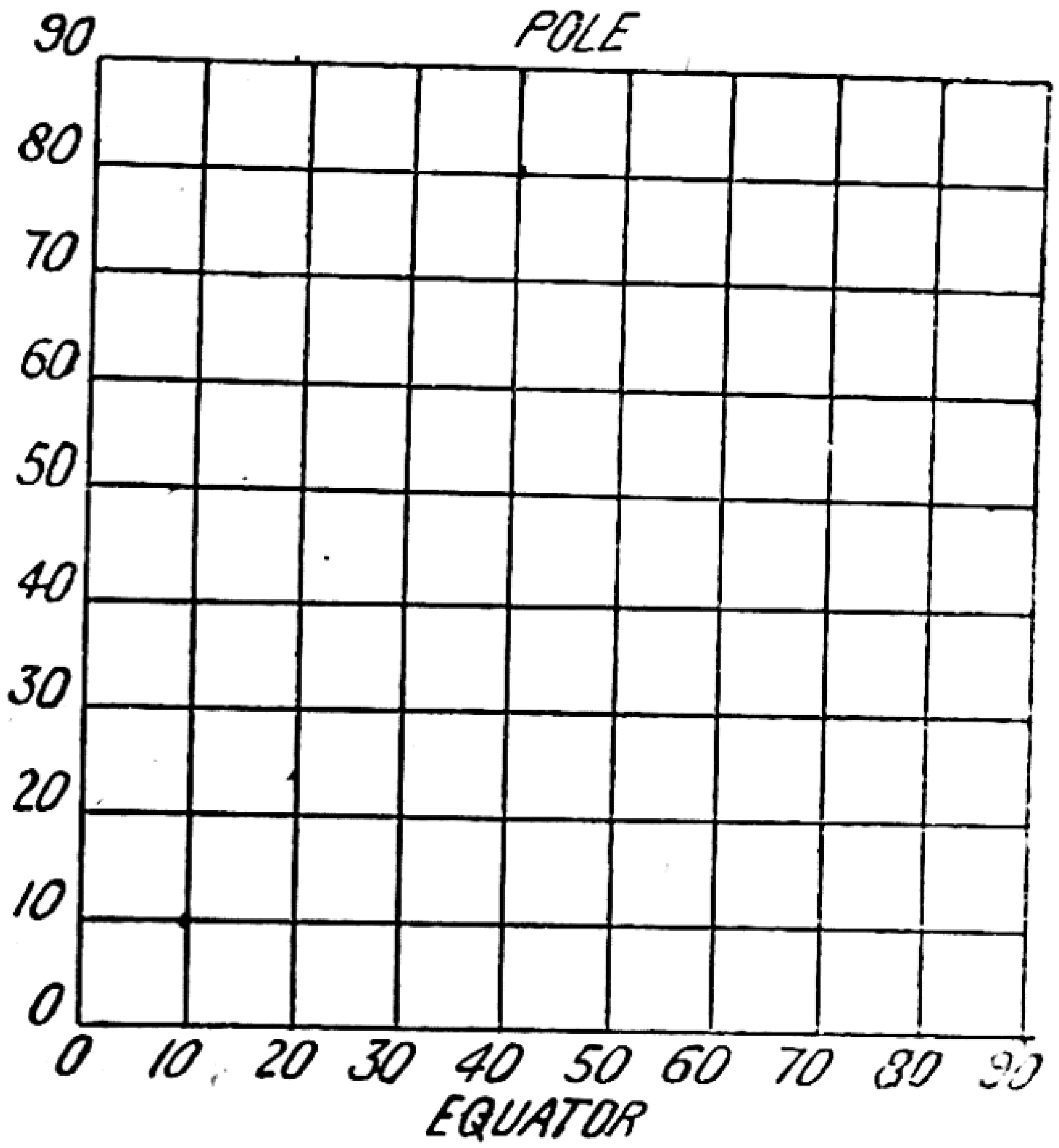


Fig. 41.

This projection is of very little use; it is neither equal-area nor orthomorphic. Its serious defect is that the poles are made of the same size as the Equator.

**88. The Cylindrical Equal-Area Projection.** For this projection the meridians and parallels are straight lines and perpendicular to one another, but the area between any two parallels is made equal to the corresponding area on the globe. The Equator is made its true length to scale, and is divided as in the simple cylindrical projection. The Poles are again the same length as the Equator.

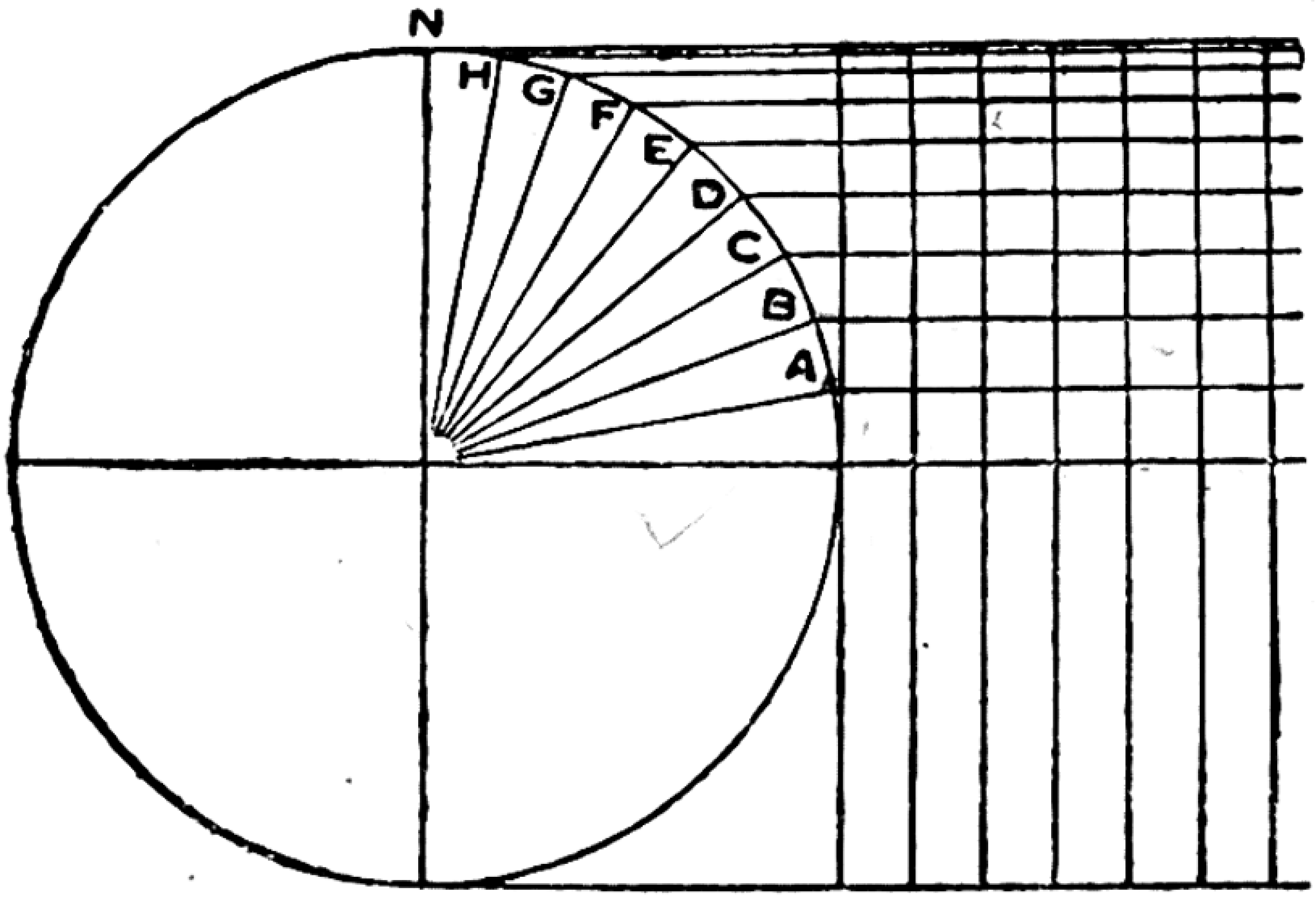


Fig. 42.

**Construction of the Graticule.** Draw to scale a circle to represent the globe, and with a protractor lay off angles at the required intervals of latitude. Then through the points A, B, C,......N, draw lines parallel to the Equator. These are the parallels of latitude,. The meridians are spaced at equal distances along the Equator.

As the area of a zone of the sphere is equal to that of the zone of the cylinder of the same height, the areas of the zone on the map are equal to those of the corresponding zones on the sphere. The projection is, therefore, truly *equal-area*, and in order to preserve the area, the shape is greatly distorted, the compression in a north and south direction being balanced by an exaggeration in an east and west direction.

It is not a very useful projection and is sometimes used for World maps to show distributions only.

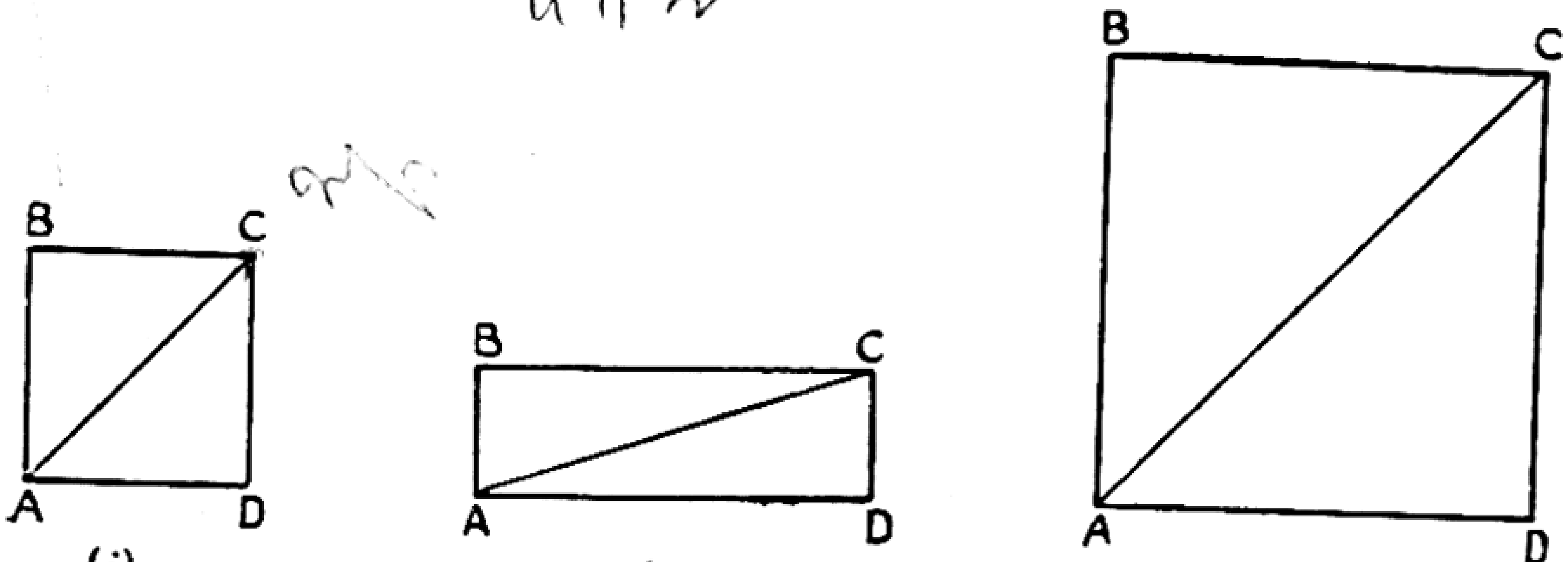
**89. Mercator's Projection (or the Cylindrical Orthomorphic Projection).** This is the best known of all projections. It is used for navigation purposes and also in nearly all atlases for maps of the world. Its chief defect is the misleading appearance of the polar areas. A cylindrical projection is orthomorphic when it has the same scale in two directions at right angles at all latitudes. We must, therefore, enlarge the scale along the meridian at each point in the same ratio as it is enlarged along the parallel.

In Fig. 43 (i) let us suppose the side of the square is equal to two inches. Its area = 4 sq. inches Point C is due north-east of A.

But if one of the sides is doubled and the other side halved as shown in Fig. 43 (ii), where AD is doubled and AB is halved, the area of this rectangle

Mercator's in the distance between 30 & 45 is not so g
as between 60 & 45, the distance between 60 & 75 becom
[illegible] still while the poles cannot be shown

remains the same as that of the original square, *i.e.*, 4 sq. inches but point C is no longer north-east of A.



(*i*) (*ii*) (*iii*)

Fig. 43.

If, however, both the sides are doubled, we get a square as shown in Fig. 43 (iii), whose area is four times the area of the original square, *i.e.*, 16 sq. inches, but point C is again due north-east of A.

The parallel of 60° is nearly half the circumfernce of the Equator. For instance, if the latitude scale at 60° is doubled, we must double the meridian scale also ; a square of 1 mile side will at latitude 60° appear to be a square of 2 miles side, with an apparent area of 4 sq. miles. Hence its chief *defect* is that the scales are correct only near the Equator in either direction and in high latitudes areas are greatly enlarged. The shape of areas is magnified but *not* distorted. The projection is therefore orthomorphic. South America is nine or ten times bigger than Greenland, whereas on this projection Greenland appears to be bigger than South America.

The great *merit* of Mercator lies in its use for purposes of navigation. As the meridians and parallels are straight lines at right angles, any straight line drawn in any direction on a Mercator chart crosses all parallels at a constant angle. Such a line is called a *rhumb line* or a *loxodrome*. A straight line crossing meridians has a constant bearing as the meridians all run true North and South. [A straight line drawn between two places on any *other* cylindrical projection cuts all meridians at the same angle but it is not a loxodrome.] The loxodrome is not a great circle : a great circle on Mercator will be a curved line. For "great circle sailing" the bearing must be altered for each day's run, so as to approximate to the great circle course.

Mercator's projection is also used for charts of ocean currents and other cases where it is important that *directions* should be readily seen.

**Construction of the Graticule.** Draw the equator according to scale, and divide it equally into 9 or 18 parts or any other convenient number. Erect perpendiculars from the points of division : these will give us the meridians, which are equidistant vertical straight lines correctly spaced.

as South [illegible] great [illegible] in length.

[illegible] poles [illegible]

is not possible to draw [illegible]

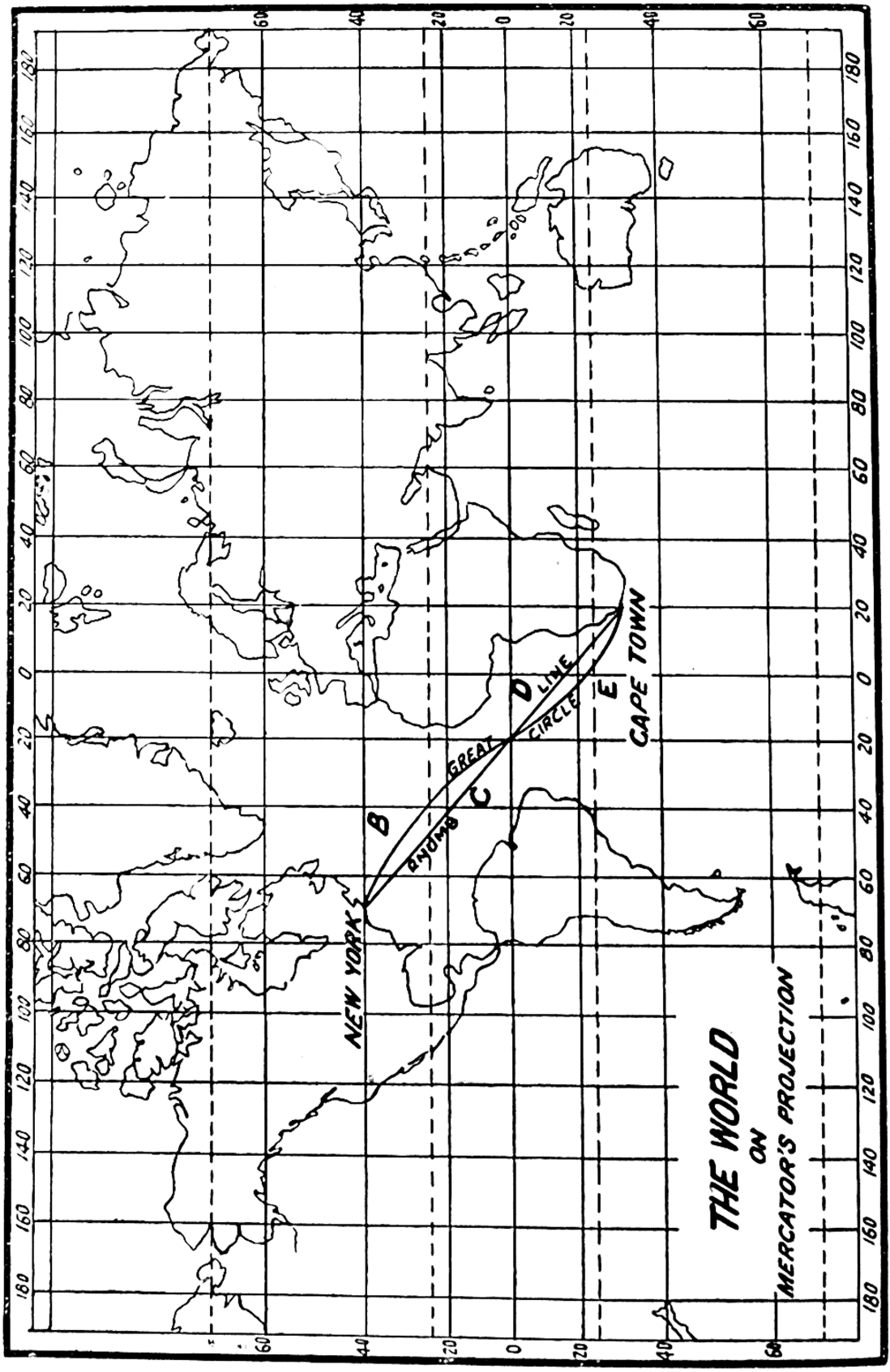

THE WORLD
ON
MERCATOR'S PROJECTION
NEW YORK
CAPE TOWN
GREAT CIRCLE LINE
RHUMB
B
C
D
E
180
160
140
120
100
80
60
40
20
0
20
40
60
80
100
120
140
160
180
60
40
20
0
20
40
60

Fig. 44.

The parallels are drawn with the help of the following table :—

| Latitude | Distance of parallel from the Equator in terms of *r* (radius of the globe to scale) | Latitude scale in terms of the scale at the Equator. |
|---|---|---|
| 0 | — | 1·00 |
| 10° | 0·175 *r* | 1·01 |
| 20° | 0·356 *r* | 1·06 |
| 30° | 0·549 *r* | 1·15 |
| 40° | 0·763 *r* | 1·30 |
| 50° | 1·011 *r* | 1·55 |
| 60° | 1·317 *r* | 2·00 |
| 70° | 1·735 *r* | 2·92 |
| 80° | 2·436 *r* | 5·76 |
| 90° | ∞ | ∞ |

**Column 2.** If the radius of the reduced globe is 2″ on a scale of 1/125,000,000, the 10° parallel will be drawn at a distance of 0·175 × 2 inches from the equator ; 20″ parallel at a distance of 0·356 × 2 inches from the Equator and so on.

**Column 3.** If the distance between meridians 10° apart at the equator is 1″, the distance of 10° parallel will be 1″ from the equator ; the distance between 10° and 20° parallel will be 1·01 inches and so on.

2p

**90. Summary.** The chief *merits* of Mercator's projection are :—

1. It shows direction accurately, hence it is useful for navigation on the sea and in the air, and for showing direction of winds, ocean currents, etc.
2. The shape of the land masses is preserved, *i.e.*, it is orthomorphic.
3. It is extremely simple to construct from table. All we have to do is to draw straight lines at their correct distances apart.

The chief *defect* is :—

The areas in higher latitudes are very much exaggerated, *e.g.*, Alaska is ⅕th of the area of U.S.A. but on this projection, it is shown to be of approximately the same size as U.S.A. Hence it is not an equal-area projection and cannot be used for distributions etc.

### CONICAL PROJECTIONS

**91. Conical Projections.** This group includes a large number of projections, several of which are in common use in atlases. As a class, they are suitable for maps of countries in temperate latitudes which do not have a great extent in latitude.

The modifications which may be made are similar to those which are made in the case of cylindrical projections, *i.e.*, they may be equal-area conicals or orthomorphic conicals.

Let us suppose that a cone of paper is placed over a globe so that it touches it along any chosen parallel. When the cone is developed, the arc of the sector will be of the same length as the parallel to which it was tangent on the globe. Such a parallel is called a *Standard Parallel*.

**92. The Simple Conical Projection with one Standard Parallel.** In the simple conic the pole of the cone is vertically above the pole of the globe and thus the globe and the cone coincide along a parallel of latitude, which is the standard parallel and is divided truly. A central meridian is drawn to represent the meridian which actually runs through the centre of the country to be mapped. The parallels are spaced along it at their true distance apart, reduction being made for scale.

**Construction of the Graticule.**—Describe a circle AEDF representing the globe on the required scale. Choose the standard parallel along the point Q. Draw the Equator AD and the polar axis EF. Produce the polar axis FE to P. At Q draw a tangent meeting FE produced in P. Make the angle BCA = 10°. With C as centre and AB as radius describe an arc of a circle. Join QC, the radius. Draw LN ⊥ CE. Then LN will give us the divisions on the standard parallel, and AB will give approximate divisions along the central meridian.

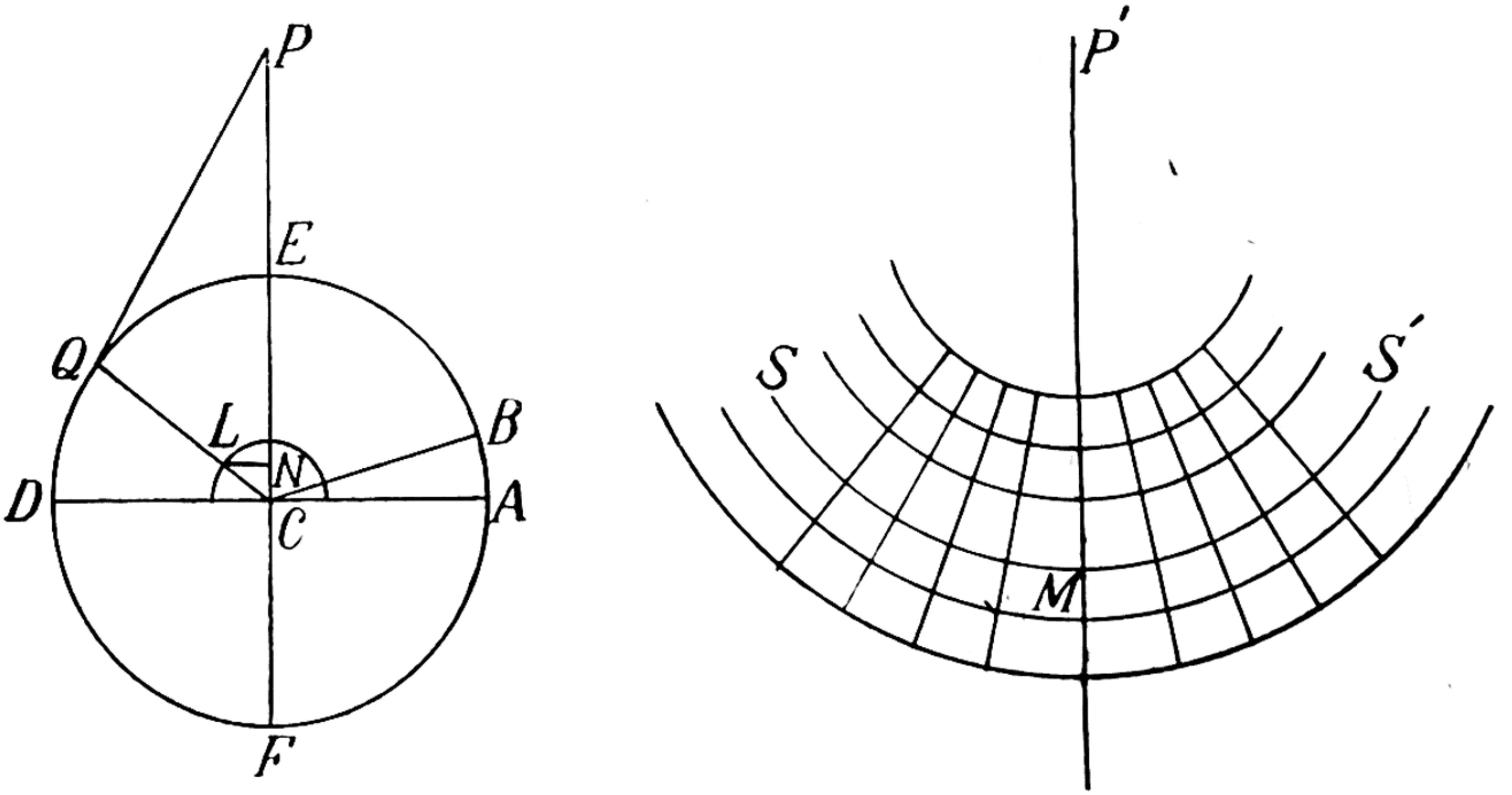


Fig. 45.

With P′ as centre and PQ as radius describe an arc of a circle SMS′, which will be the standard parallel. Draw any line P′M as the central meridian. Mark off on P′M (working outwards from M) divisions equal to AB. Mark off along SMS′ divisions equal to LN. With P′ as centre and the divisions along PM as radii describe arcs of circles. Join P′ with divisions on the standard parallel SMS′.

This approximate method is very nearly accurate. The error lies in assuming that AB is a straight line, which matters little in small scales. Any parallel of latitude may be taken as the standard parallel provided it is the central parallel of the area to be projected.

This projection is much used for small countries which have no great extent in latitude, *e.g.*, Ireland and Denmark.

The scale is correct on the standard parallel and along the central meridian. The other meridians are radii of a series of concentric circles; the scale along them is also correct, *i.e.*, the distance from P′ to the parallel corresponds to the distance on the globe. The scale along the other parallels is too great.

The chief *merit* of this projection is that it is a compromise between an orthomorphic projection and an equal-area projection. The distortion for small areas is small. It can be used for general maps of countries in the Temperate zone.

Its chief *defect* is that distortion occurs both north and south of the standard parallel and increases as the distance from the parallel increases.

**93. The Polyconic Projection.** The basic idea underlying the Polyconic Projection may be arrived at as follows : Divide the Earth's surface into narrow belts of latitude ; draw a strip of a tangent cone to each of them ; project upon the tangent cone the surface of the globe from the centre. Every parallel belt has its own radius.

The Polyconic is used in Geological survey sheets.

A modification of the Polyconic is used for the **International map** on a scale of one to one million (1/1,000,000) each sheet of which covers 4 degrees of latitude and 6 degrees of longitude. The 1/M Survey Sheets of India cover 4 degrees of latitude and 4 degrees of longitude.

The advantage of this modification lies in its small scale-error which is less than 1/1300 on each sheet. It is possible to fit together one sheet to another either in north-south or east-west direction. Nine adjacent sheets may be fitted together with only a slight amount of stretching.

## EXERCISES

1. How would you recognize (*a*) a Mercator Projection, (*b*) a Conical Projection, (*c*) a Cylindrical Equal-area Projection ?

2. Why may a map of the world on Mercator projection be suitable for showing distribution of rubber but not that of wheat ?

3. What projection would you use to show air-mail route from England to India ? Give reasons for your answer.

4. Say why you consider the following projections unsuitable :
   (*a*) Mercator for Canada and Siberia ;
   (*b*) Simple conic with one standard parallel for South America.

5. (*a*) Explain the relative advantages and disadvantages of conical and cylindrical projections
   (*b*) Show how Mercator's projection is helpful to a mariner.
   (*Punjab Univ., Inter., Supp. 1932*)

6. What class of projections are generally used for maps of the equatorial regions ? What is the principle underlying Mercator's Projection ? What are its advantages ?
   (*Punjab Univ., Inter., 1933*)

7. Draw a net of parallels and meridians for every 30° on the Cylindrical Equal-area Projection for the reduced Earth of two inches radius. (*Punjab Univ., Inter. 1933*)

8. Draw the net for a simple Conical projection with one standard parallel (50°N) for a globe 5 inches in radius, for an area extending from latitude 30°N. to 70°N, and for 60 degrees of longitude. Show meridians and parallels 10° apart. (*Punjab Univ. Inter. 1934 and 1939*)

9. What is Mercator's Projection ? In what maps of your Atlases is it usually employed ? Give its advantages and disadvantages.

X. What projection has been employed in the 1 to 1M sheets of the Survey of India that you have studied ?

Mercator Projection (*Punjab Univ, Inter., April 1941*)

# CHAPTER X

## MAP PROJECTIONS—II

**94. Conventional Projections.** We have so far discussed three generalised types of Projections. Apart from these three, there is a large and important class that cannot be related to any of them. These may be called Conventional Projections. These projections are very widely used although they vary considerably in construction and appearance.

**95. The Globular Projection.** This projection is much used in atlases for maps of the World in hemispheres, although it has no particular merits.

**Construction of the Graticule.** Describe a circle to scale to represent one hemisphere. Divide the equatorial diameter and the central meridian into 18 (or whatever number may be required) equal parts. Set off from the centre angles of 10° (or whatever angle may be required), and note where these cut the circumference. Draw circles through the Poles and the divisions on the Equator; these circles will represent the meridians. Draw curves through points on the circumference and the corresponding points on the central meridian. These curves will represent the parallels of latitude.

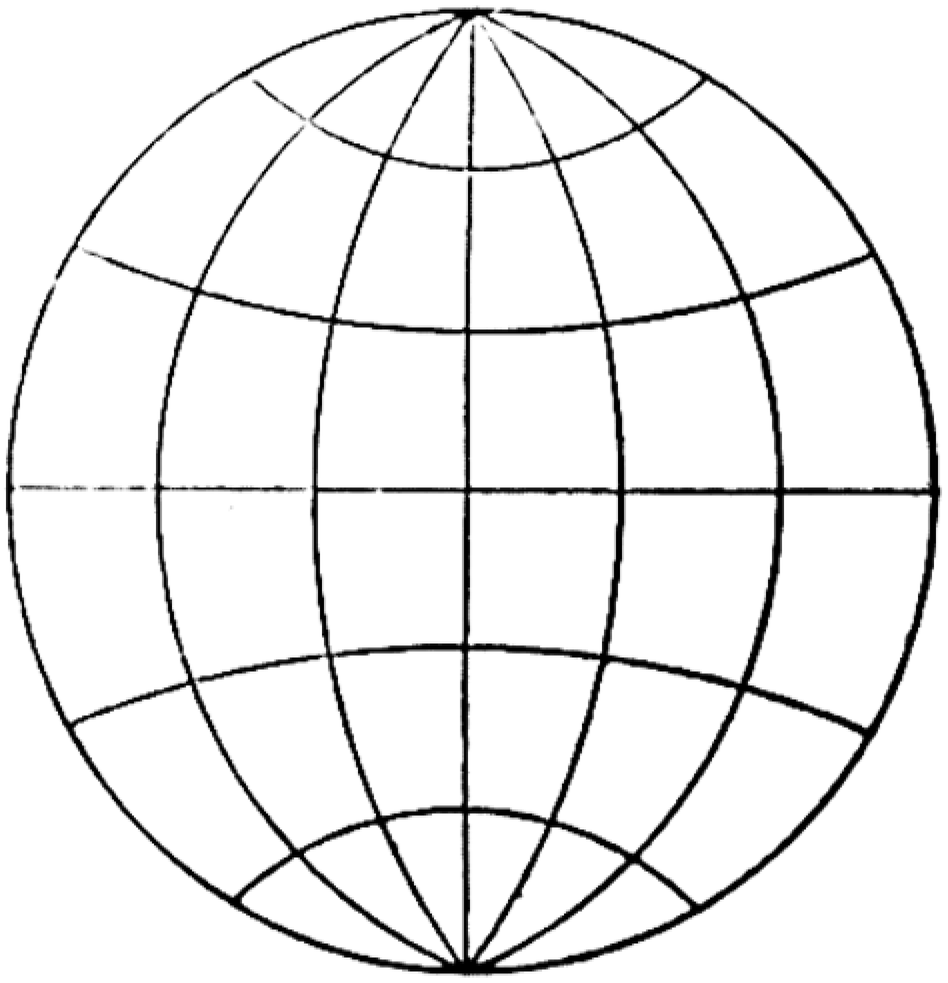


Fig. 46.

**96. Mollweide's or Elliptical Equal-Area Projection.** Mollweide's Projection is an ellipse in which the major axis (representing the Equator) is exactly twice as long as the minor axis (representing the distance from pole to pole along the central meridian).

The parallels of latitude are horizontal straight lines though they are *not* spaced at equal distances, the distance between the parallels decreases as the Poles are approached.

The central meridian is a straight line, all other meridians are curved, *i.e.*, ellipses; the curve becomes more pronounced towards the margins. Hence marginal areas are misrepresented but as a greater portion of the marginal areas on this projection shows oceans, this may not be regarded as a serious defect.

**Construction of the Graticule.** Construct a circle equal in area to a hemisphere on the required scale.

The area of a circle $= \pi r^2$.

" " the hemisphere $= 2\pi R^2$

where $r$ and $R$ are the radii of the circle and hemisphere respectively.

Equating these two expressions—

$$\pi r^2 = 2\pi R^2.$$

We get $$r = \sqrt{2}\, R.$$

Hence on a scale of 1/250,000,000. $R = 1$ and $r = 1{\cdot}414$.

This indicates the amount of stretching required to raise a circular plate of metal so as to form a hemispherical bowl.

Describe a circle with radius $= r$. Produce the equatorial diameter each way making HF=HO and KG=OK. Then describe the ellipse GBNAFS.

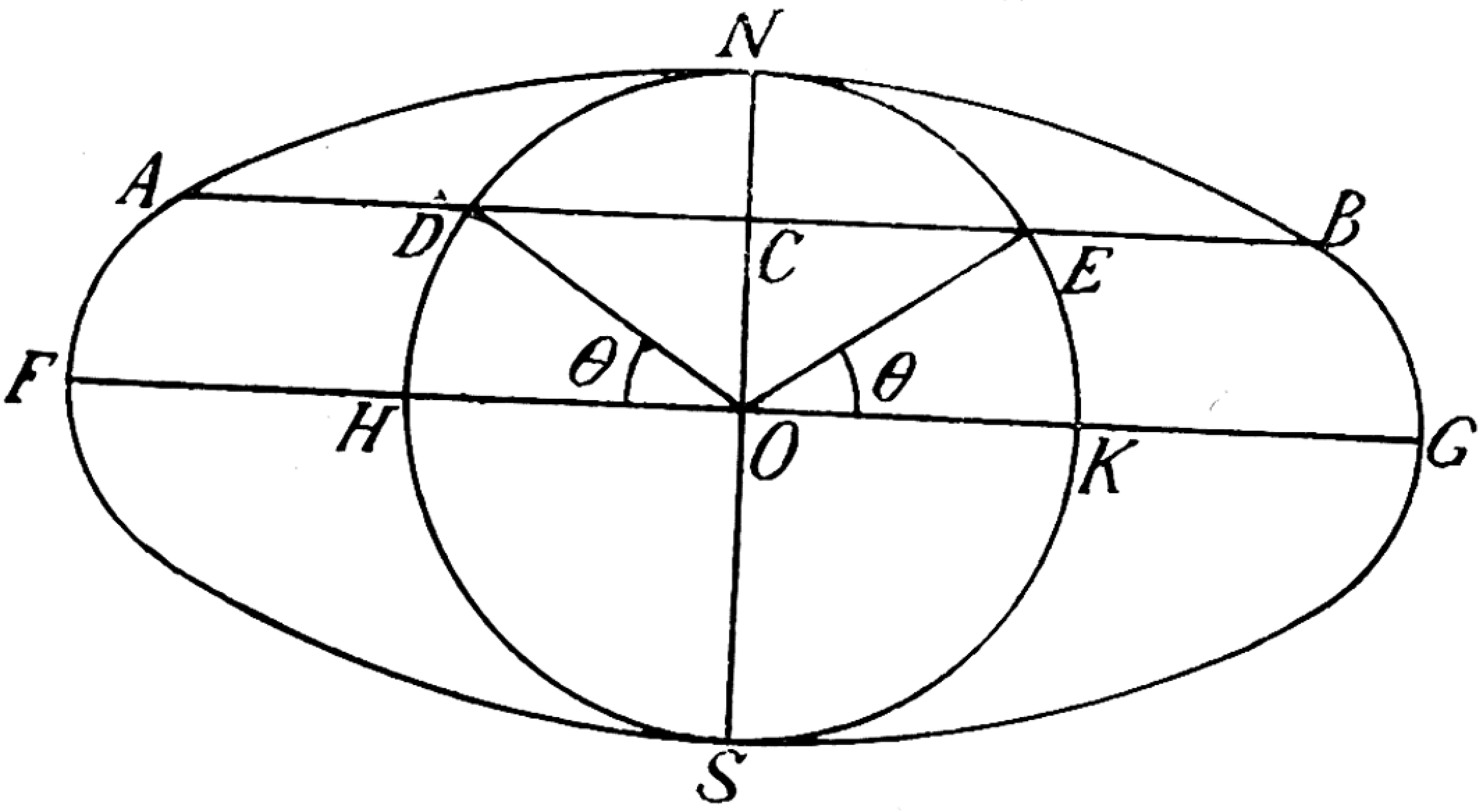


Fig. 47.

The area of the ellipse is double that of the circle, and is, therefore, equal to the area of the whole globe. The line NS denotes the central meridian from pole to pole and FG the Equator.

Divide the Equator FG into 36 (or any other convenient number) equal parts. Through the points of division with NS as axis draw ellipses. These will be the *meridians*. From the properties of the ellipse we learn, that the area of each of these gores between consecutive meridians drawn at intervals of 10° will be one thirty-sixth of the whole area of the globe.

It remains now to divide these strips or gores by parallels of latitude into the same areas as the corresponding gores on the globe. This is a difficult problem and requires a knowledge of trigonometry. The ellipse is divided into narrow strips having the same area as the zone of the globe between the same parallel of latitude. *The distance between the parallels of latitude decreases as the latitude increases.*

The following table gives the distance from the Equator at various parallels of latitude on Mollweide's projection, where $r$ is the radius of the central circle, and $R$ is the radius of the Hemisphere.

| Parallel of Latitude | Distance from the Equator in terms of the radius of the circle ($r$) | Distance from the Equator in terms of the radius of the Hemisphere ($R$) |
|---|---|---|
| 10° | $0{\cdot}137\ r$ | $0{\cdot}197\ R$ |
| 20° | $0{\cdot}272\ r$ | $0{\cdot}384\ R$ |
| 30° | $0{\cdot}404\ r$ | $0{\cdot}575\ R$ |
| 40° | $0{\cdot}531\ r$ | $0{\cdot}749\ R$ |
| 50° | $0{\cdot}651\ r$ | $0{\cdot}921\ R$ |
| 60° | $0{\cdot}762\ r$ | $1{\cdot}074\ R$ |
| 70° | $0\ 862\ r$ | $1{\cdot}218\ R$ |
| 80° | $0{\cdot}945\ r$ | $1{\cdot}337\ R$ |
| 90° | $1{\cdot}000\ r$ | $1{\cdot}414\ R$ |

The chief *merits* of Mollweide's projection are as follows :—

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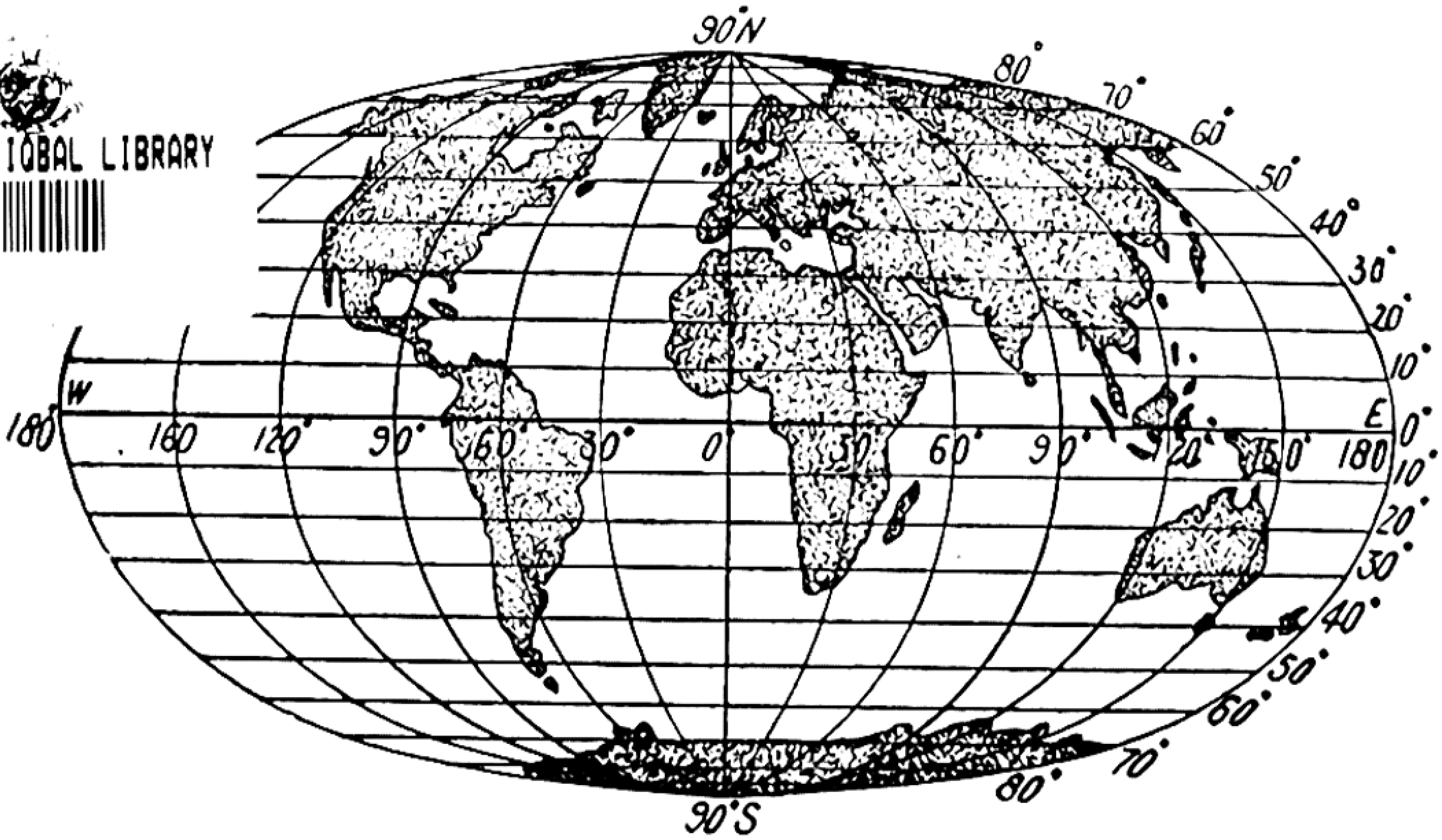

Fig. 48.

1. It is an equal-area projection, *i.e.*, all areas on this projection are truly represented. Compare, for instance, Alaska and U.S.A., and Greenland and South America on Mercator's and Mollwiede's projections. Hence the projection is much used for showing world-distribution of commodities, density of population, etc.

2. The areas in the centre of the map, *e.g.*, parts of Europe and Africa preserve their shape.

The chief *defects* of Mollweide's projection are as follows :—

1. It is not an Orthomorphic projection, *i.e.*, the shape is distorted. The distortion is greatest along marginal areas, but as these areas are in ocean, the marginal distortion is not serious for all practical purposes.

2. It is not a true bearing projection, hence it cannot be used to show ocean currents, winds, routes, etc.

3. The construction of the net-work is not easy.

**97. The Choice of a Projection.** The projection to be selected for any map depends upon two factors :—

1. The extent of the area to be represented, and

2. The purpose for which the map is mainly required.

The projection should fulfil both these considerations.

A few examples will make the matter clear.

Suppose a map is required to show the chief rice-producing areas of the world. We know that the chief rice-producing areas are in tropical and sub-tropical regions, hence the polar regions may be left out. Secondly we want to obtain at a glance an idea of the respective sizes of each area. Hence the best projection will be the Cylindrical Equal-area, as the distortion of shape within 30° of the Equator is not too great.

Consider, again, a map to show the wheat-growing areas of the world. Equal area Cylindrical Projection will not do for this purpose as the wheat-growing areas are nearly all in temperate latitudes and in both hemispheres. The shape of the areas must be maintained as they are large areas. Hence Mollweide's projection will be best for this purpose. Should, however, an equal-area map of a country say the United States, showing the distribution of maize, be required, a Conical projection will be suitable for this purpose.

Other things being equal, a cylindrical projection is suitable for equatorial regions, a conical for temperate regions, and a zenithal for polar regions. For world maps Mercator's and Mollweide's projections are commonly employed. The Royal Air Force have adopted Mercator's projection for air maps; in this and in showing main winds and ocean currents, *direction* is the most important criterion; hence the use of Mercator's projection.

**98. Identification of Projections.** The various projections can be identified with the help of the following table :—

1. *Parallels are straight lines—*
   - (*a*) Meridians are straight lines spaced evenly and perpendicular to the Equator and
     - (*i*) Parallels are equidistant—**Simple Cylindrical.**
     - (*ii*) Parallels are close towards the poles—**Cylindrical Equal-area**
     - (*iii*) Parallels are wider apart towards the poles—**Mercator**.
   - (*b*) Meridians are curved, and
     Parallels are close towards the poles—**Mollweide.**
2. *Parallels are concentric circles—*
   Meridians are radiating straight lines, and
   Parallels are equidistant and are concentric circles—**Simple Conic.**

## EXERCISES

1. Why is it necessary to study map projections ? Briefly describe the general classes of projections

2. Write short notes on :—
   Graticule, great circle, small circles, loxodrome.

3. Explain what is meant by a map projection. Compare the relative merits and defects of Mercator's and Mollweide's projections. (*Indian Police, Service 1930*)

4. What type of projection would be suitable for the following ;—
   - (*a*) The distribution of cotton in the world,
   - (*b*) Political divisions of the world,
   - (*c*) Chief fisheries of the world,
   - (*d*) A general map of Sweden and Norway,
   - (*e*) A general map of Central Europe,
   - (*f*) The forests of Southern Countries,
   - (*g*) The distribution of tea in the Eastern Hemisphere ?

5. Construct a graticule for the Mercator projection taking the Equator as 12 inches.

6. Examine the following maps in the Oxford Atlas (Bartholomew) and decide which projection is used for each, giving reasons for your choice. Suggest alternative projections :—
   (*a*) Africa. (*b*) Canada. (*c*) U.S.A. (*d*) Europe. (*e*) The British Isles. (*f*) India.

7. Construct a simple Conical graticule with one standard parallel on the scale of 1/100,000,000.

8. Construct a graticule for a map of the World on Mollweide's projection, selecting such scale as will make the Equator 12 inches long and inserting meridians every 30 degrees and parallels every 10 degrees,

9. Describe any equal-area projection suitable for the whole Earth, and compare it with Mercator's projection (*a*) as regards construction of the net and (*b*) as regards purposes for which it is suitable. Molweide *(Punjab Univ., Inter., 1934)*

10. Name the principal advantages and defects of any two commonly used map projections. Describe simply the principle underlying any one of them.

*(St. Bede's Training Cert. Exam. 1934)*

11. Name any two projections suitable for the whole earth and compare them (*a*) as regards construction of the net, and (*b*) as regards geopraphical purposes for which each may be suitable.

*(Punjab Univ. Inter., 1935)*

12. Compare and contrast the Mercator's Projection with any equal-area projection for world maps, bringing out the advantages and disadvantages of each for geographical purposes.

*(Punjab Univ., Inter., April 1939)*

13. What projections would you select for drawing maps of

[illegible]

(*a*) the lands round the Arctic Ocean,

(*b*) Africa showing equal-area,

(*c*) The prevailing winds and ocean currents of the Atlantic Ocean ?

Give reasons for your choice in each case. *(Punjab Univ., Inter., Sept,, 1939)*

# APPENDIX

## APPARATUS

The following apparatus will be found necessary for the practical work described in this book :—

(*a*) *For Field Work*

Gunter's chain
Arrows

Plane Table
Box compass
Alidade
Spirit level
Measuring Tape
Plumb-bob and fork
Poles and Flags

Prismatic compass
Clinometer
Theodolite

(*b*) *Meteorological apparatus*

Aneroid Barometer
Fortin's Barometer
Barograph
Thermograph
Maximum and minimum thermometers
Wet and dry bulb thermometer
Rain gauge

**Maps etc.** Survey sheets and Characteristic sheet of conventional signs may be had from The Map Record and Issue Office, Survey of India, Calcutta or their representatives, The Punjab Religious Book Society, Lahore.

The Indian Daily Weather Report may be had from The Director General, Meteorological Observatories, Poona.

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